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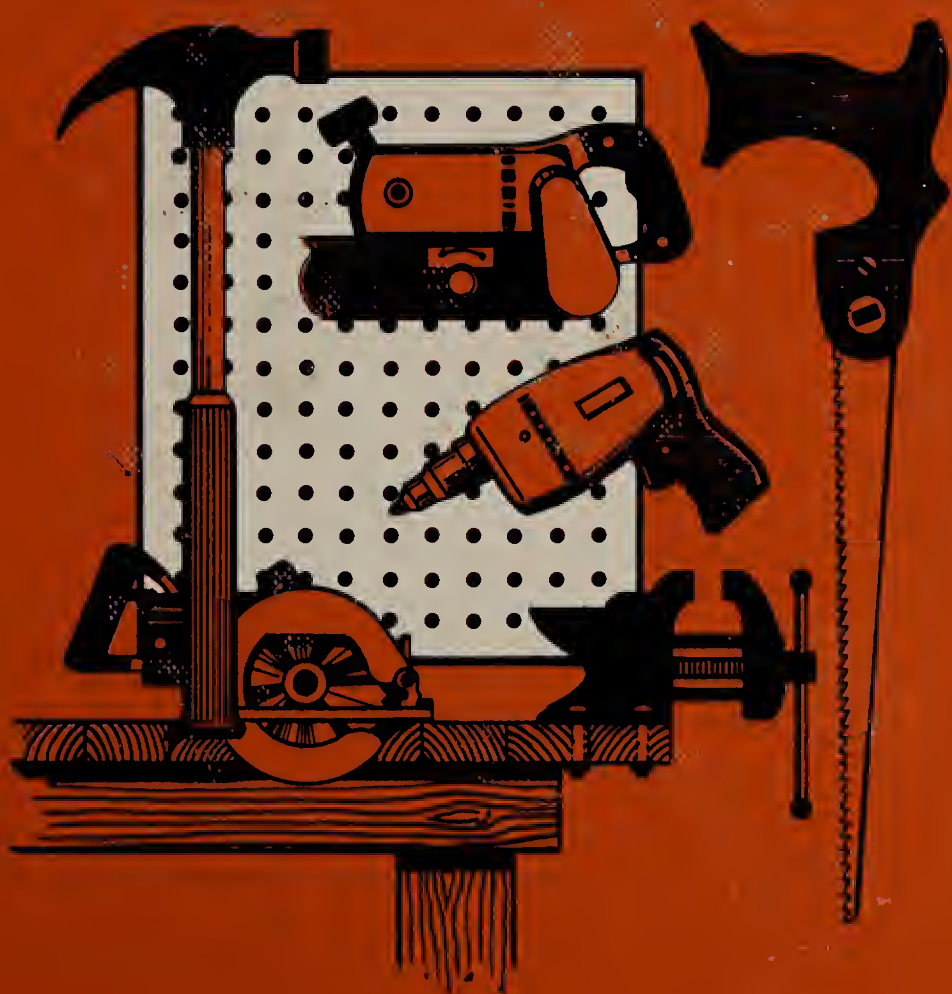
HOME WORKSHOP and TOOL HANDY BOOK

by Edwin P. Anderson



HOME WORKSHOP & TOOL HANDY BOOK

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Foreword

The do-it-yourself craze has been increasing around the world for many years, and it will undoubtedly continue to grow for many more years. Frequently do-it-yourselfers work in a cold garage, the kitchen, or even the living room. Naturally, a person's best work cannot be done under such unfavorable conditions, so many do-it-yourselfers are setting up workshops.

This practical manual is written for the home craftsman, student, or beginner who is uncertain as to the type of workshop he needs. The selection of a location for the work area, the best possible layout within the shop, the selection of hand tools and power tools, and safety practices to observe once the shop is set up are all explained in easy-to-understand terms.

Hundreds of illustrations of every phase of the workshop are included to help you actually see what needs to be done. Charts and various listings will prove to be of lasting value as references as you work in your new shop. Finally, the detailed descriptions of the tools and their uses will be of use as you expand your equipment and workbench facilities.

E. P. Anderson

Contents

CHAPTER 21

CHAPTER 22

CHAPTER 23

CHAPTER 1

Planning the Home Workshop

A prime consideration in planning a workshop is choice of location; this choice should be influenced by the following important factors:

1. Space requirements for present and future use.
2. Convenience, that is, proximity to the home so that the owner loses the least amount of time walking back and forth to his workshop.
3. Noise and vibrations from power-operated tools. These may be of considerable annoyance, particularly when the workshop is located in a basement with living quarters above.
4. Provisions for heat, water, and ventilation, and enough window space to provide ample light in daytime.
5. Provisions for a wiring system adequate for all power tools and any artificial lighting that will be needed.

If all of the foregoing points are carefully considered, the correct decisions with respect to workshop location will undoubtedly be made. By experience it has been found that most home workshops are finally located in the basement whenever sufficient space is available. In homes having no basement, a workshop may be built as an extension or wing onto the home, as a part of the garage, or as a separate, adjacent building.

A workshop separate from the home has the advantages of good light and ventilation, freedom from noises and vibrations being transmitted to the home, and, finally, a better all-round layout since the owner is free to design his shop as he pleases without space limitations imposed by his existing basement.

In situations where the foregoing locations are not available or practical, an attic workshop location may be considered. While this may not be an ideal location, it will offer a solution, provided that the floor is strong enough to support the equipment with safety and that noise and vibrations can be properly dealt with. It should be noted, however, that while light and ventilation will not be a difficult problem in an attic location, carrying of materials, finished work, and tools up and down long, narrow stairways will be a detrimental factor.

Light and Ventilation—The problem of light and ventilation can usually be solved without too much difficulty. When the workshop is located on or above the ground level extra windows can be installed, if more light and ventilation are needed.

In a projected basement workshop the problem of too few or too small windows may in many cases be solved by enlarging the existing window area. This will add to the expenses, but in many instances it may be a worthwhile investment since it will improve the home exterior and provide for a dry and well-ventilated basement. Where very little daylight can be obtained, provision must be made for a sufficient number of properly located electric light outlets. Ventilation in such cases is commonly accomplished by a forced-draft system using an electric fan and louver.

Heating—In basement locations where a home heating plant is an integral part, the radiant heat from the furnace and boiler is usually sufficient to take care of all heat requirements, particularly so since best working comfort is obtained in a workshop having an average temperature of about 65° F.

Where required, a selection may be made between a small pot-bellied laundry stove, using coal or wood, and an electric heater. Electric heaters are preferred only in locations where the cost of electrical energy is low or where the cubic content of the workshop is small. Another efficient heating unit suitable for the home workshop is the oil heater. This type of unit burns relatively cheap fuel oil and radiates an abundance of heat for the amount of fuel consumed. The fuel-oil heater is usually attractive in appearance as well as economical to operate.

Wiring—An adequate and properly installed electric wiring system is an important part of any successful workshop. Under no

conditions should the home owner attempt to extend the existing wiring system to include the connections required for additional lights and power tools. It should be clearly borne in mind that the installation of the required branch circuits for light and power is a job for a licensed electrician, and must conform with the National Electrical Code and all local codes.

After determining number and wattage of the various power tools required for the workshop, the next step is to determine the outlets needed to properly serve this equipment. Plenty of outlets, carefully placed, will prevent the use of extension cords, which can be dangerous as well as unsightly. Extension cords present a double hazard, one from tripping and the other from the electrical hazard of short circuits caused by frayed cords.

For the average home workshop two circuits leading from the main control center, Figs. 1 and 2, are usually sufficient. That is, one circuit to be used for the power tools and the other for shop

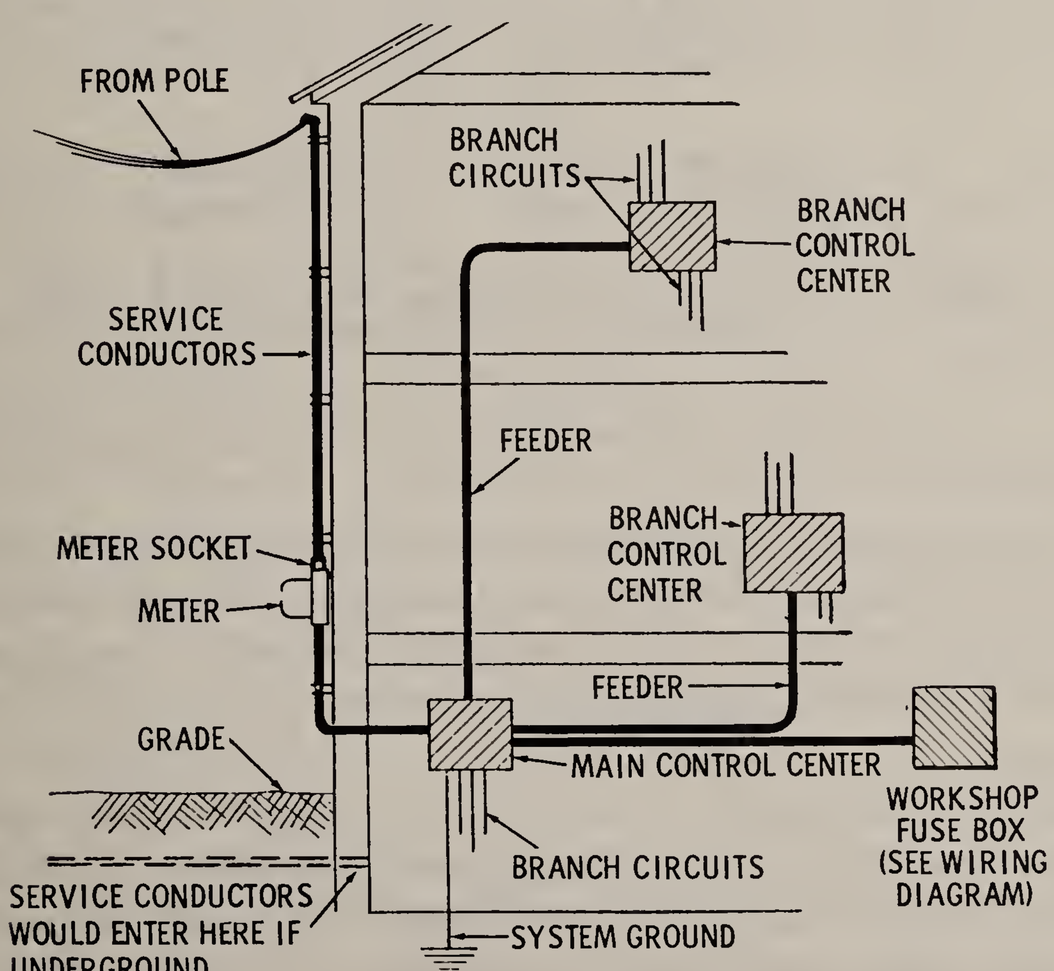


Fig. 1. Schematic arrangement for typical distribution system in a modern home. The basement workshop feeder is tapped at the main control center and terminates at the workshop fuse box.

lighting. One reason for having separate circuits for light and power is that if a power tool is overloaded and a fuse is blown, the lighting circuit will be unaffected. Another reason is to avoid dimming of lights when starting motors.

The power load imposed on the line by any individual machine is shown on the motor name plate. If more than one machine is to be operated simultaneously, the total load on the power line will be obtained by adding up the current ratings of all motors. The wire used in the lighting circuit should not be smaller than No. 14, and in the circuit for the power outlets No. 12 wire or

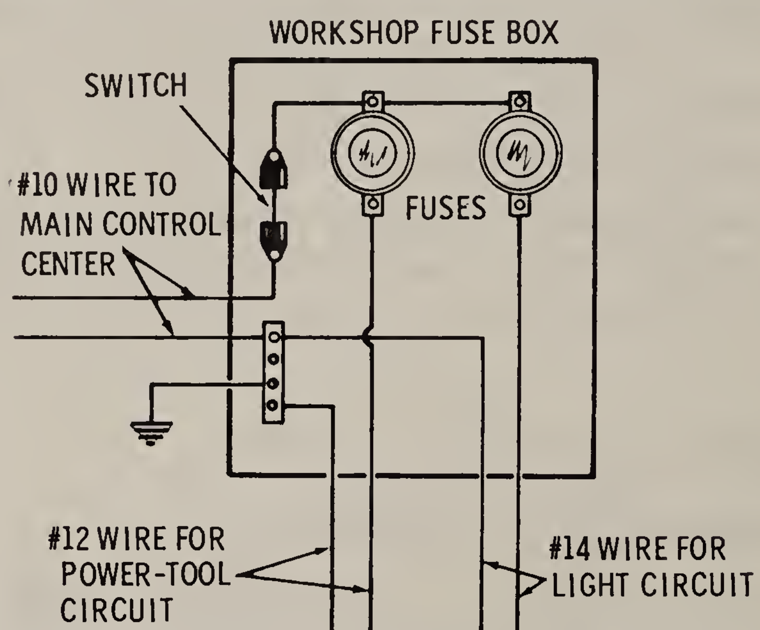


Fig. 2. Wiring diagram illustrating connections for typical two-circuit workshop fuse box.

larger should be used, depending upon the total power load requirements.

As noted in Fig. 2, an extra switch and fuse box is required to control the workshop light and power circuits. This box should be located out of reach of children, and should be equipped so that the switch may be locked in the open position for the sake of safety.

The feeder circuit between the main control center and the foregoing switch box should be as short as possible and should be of No. 10 wire or larger. In some localities the code requires that all wiring below ground level be encased in conduits, whereas in others BX, or armored cable, is permissible.

An important factor in determining the wire size is the length of run from the control box to the last outlet. A No. 12 wire

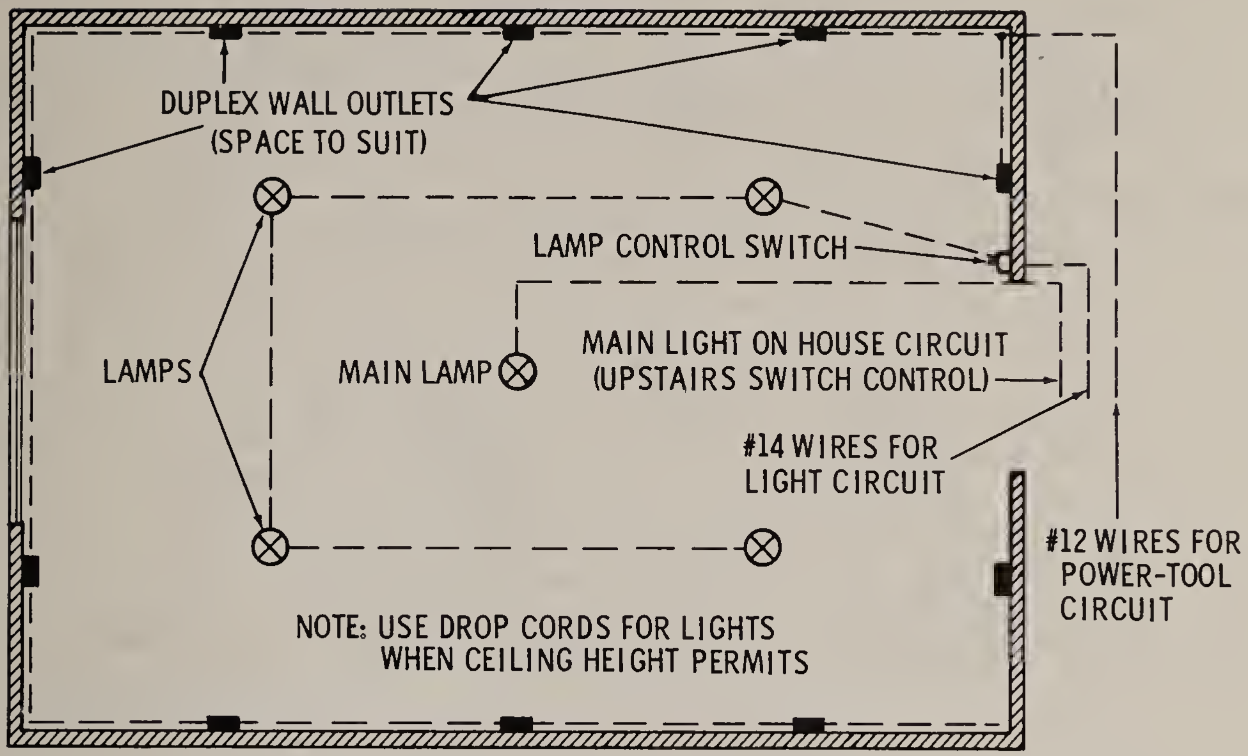


Fig. 3. Wiring arrangement for typical basement workshop. Although two circuits are sufficient in most instances, a separate circuit may be provided for the main lamp which is usually controlled by a separate switch located at the upstairs entrance to the basement or workshop.

should not exceed 50 feet in length if the allowable voltage drop of 2 percent at 15 amperes is to be maintained throughout its entire length. If the total drain on the line is to be no more than 5 amperes (which is equivalent to 575 watts at 115 volts AC) it is possible to use a No. 14 wire up to 90 feet in length without exceeding the allowable 2-percent voltage drop.

Table 1 shows the various sizes of rubber-covered solid wire used in home wiring, the maximum capacity in amperes, and the maximum length for the amperage that is to be carried. The table can also be used to determine the size wire required for any outlet or series of outlets that are to be installed, if the total amperage or wattage is known.

Thus, for example, if it is assumed that the power tools will never draw a combined load of more than 20 amperes or 2,300 watts, they can be adequately supplied with a No. 12 circuit if the total length of the line from the control box does not exceed 37 feet. If the circuit is more than 37 feet long but does not exceed 60 feet, a No. 10 circuit should be used, provided all outlets are to supply the full amperage within the 2-percent allowable voltage drop.

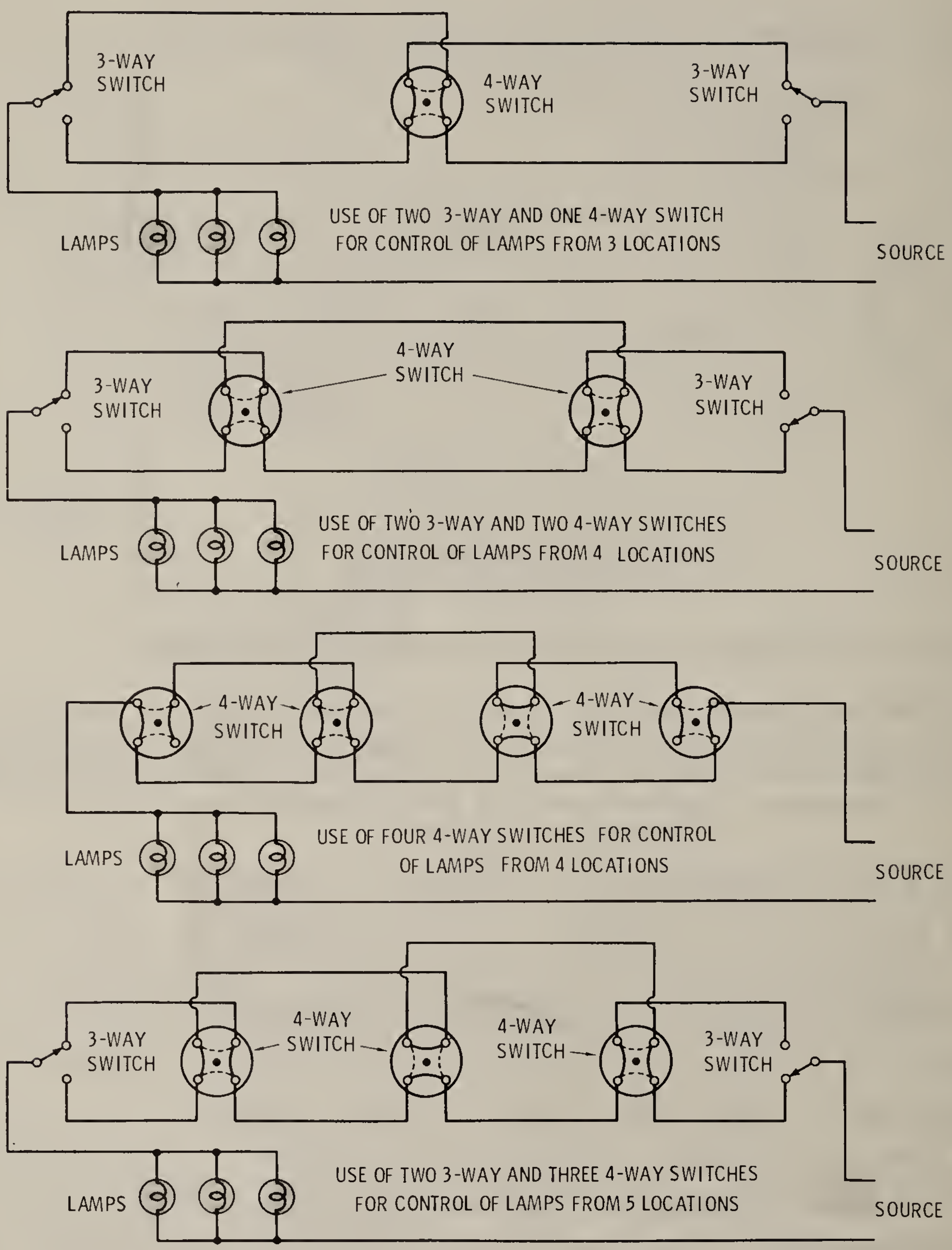


Fig. 4. Various lamp control schemes. The series of connection diagrams shown illustrate the conventional methods of control when using 3- and 4-way switches. It is obvious that for any additional point of control desired, a 4-way switch connected the same as the middle switch must be used.

Grounding—To protect the user from possible shock, all exposed metal parts of electric power tools should be well grounded. Then, if an insulation breakdown occurs between the interior and exterior of a tool, a fuse may blow, but the person using the tool will be in no danger of shock. Grounding of equipment is especially important where dampness is present.

Table 1. Type "R" Rubber-Covered Copper Wire

Wire Size A.W.G.* or B & S**	Max. Cap in Amps	Max. Dist. in Feet with 2% Voltage Drop @ 115V									
		Amps									
		5	10	15	20	25	35	45	60	80	100
No. 14	15	90	45	30							
No. 12	20	140	70	50	37						
No. 10	25	220	110	75	60	45					
No. 8	35	360	175	125	90	75	55				
No. 6	45	560	280	190	150	120	85	70			
No. 4	60	900	450	300	230	180	140	110	80		
No. 2	80	1400	750	475	370	300	220	170	130	95	
No. 0	105	2300	1200	750	580	450	325	260	200	150	120
Wattage At 115V		575	1150	1725	2300	2875	3450	5175	6900	9200	11,500

* American Wire Gauge
** Brown & Sharpe

A water pipe or a grounded metallic conduit will serve as a grounding connection. In the absence of the foregoing, a rod driven into the ground at least 2½ feet will serve as an artificial ground.

HOME WORKSHOP LAYOUT

The placement of power tools for most efficient use is predicated upon several basic principles, each playing an important role not only in the matter of tool selection, but in the final cost and all-round satisfaction as well. It is of course, necessary to have adequate electrical wiring and a sufficient number of power and light outlets in addition to proper ventilation in any shop.

Minimum-Size Layout—In a projected workshop having a limited available area of, say, 8 × 10 feet, it is obviously impossible to plan for a complete set of single-purpose power tools without unduly restricting the necessary working space.

When conditions permit, the use of one compact multipurpose power tool should be considered for any limited workshop area. The comparison in layouts and tool arrangement for an 8 × 10-foot workshop is given, with various single-purpose power tools (Fig. 5) and one multipurpose tool (Fig. 6).

These layouts show that a considerable saving in floor space is obtained when using the multipurpose tool. When placed as shown—that is, near the center of the floor—the multipurpose

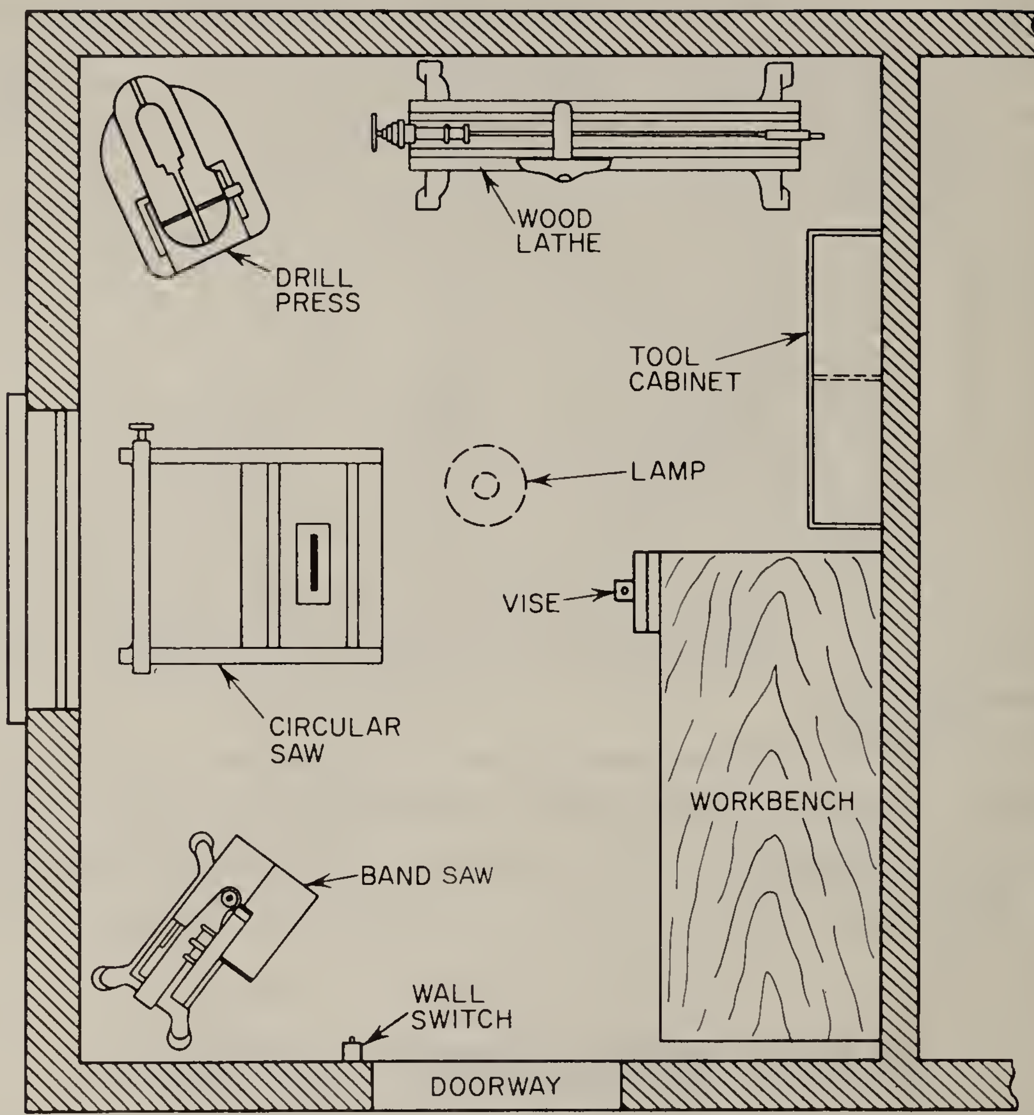


Fig. 5. Typical 8 × 10-foot basement workshop layout with four single-purpose power tools. Since other arrangements are possible, the location of the various power tools as well as the number of tools required should be carefully considered in each instance.

tool enables the operator to work on long boards, or large panels, without ramming the work against the wall during the operation. Prior to the purchase of any power tool, therefore, a careful analysis of the necessary workshop space should be considered. This again will depend upon the type of work contemplated, the amount of space required for hardware and lumber storage, etc.

Medium-Size Layout—Where a moderate amount of workshop space, say 13 × 18 to 13 × 20 feet, is available and single-purpose power tool units are required, the individual machines may be placed for most efficient use as illustrated in Fig. 7. The circular saw and jointer should be placed near the center of the workshop for free movement when working with long boards and large panels.

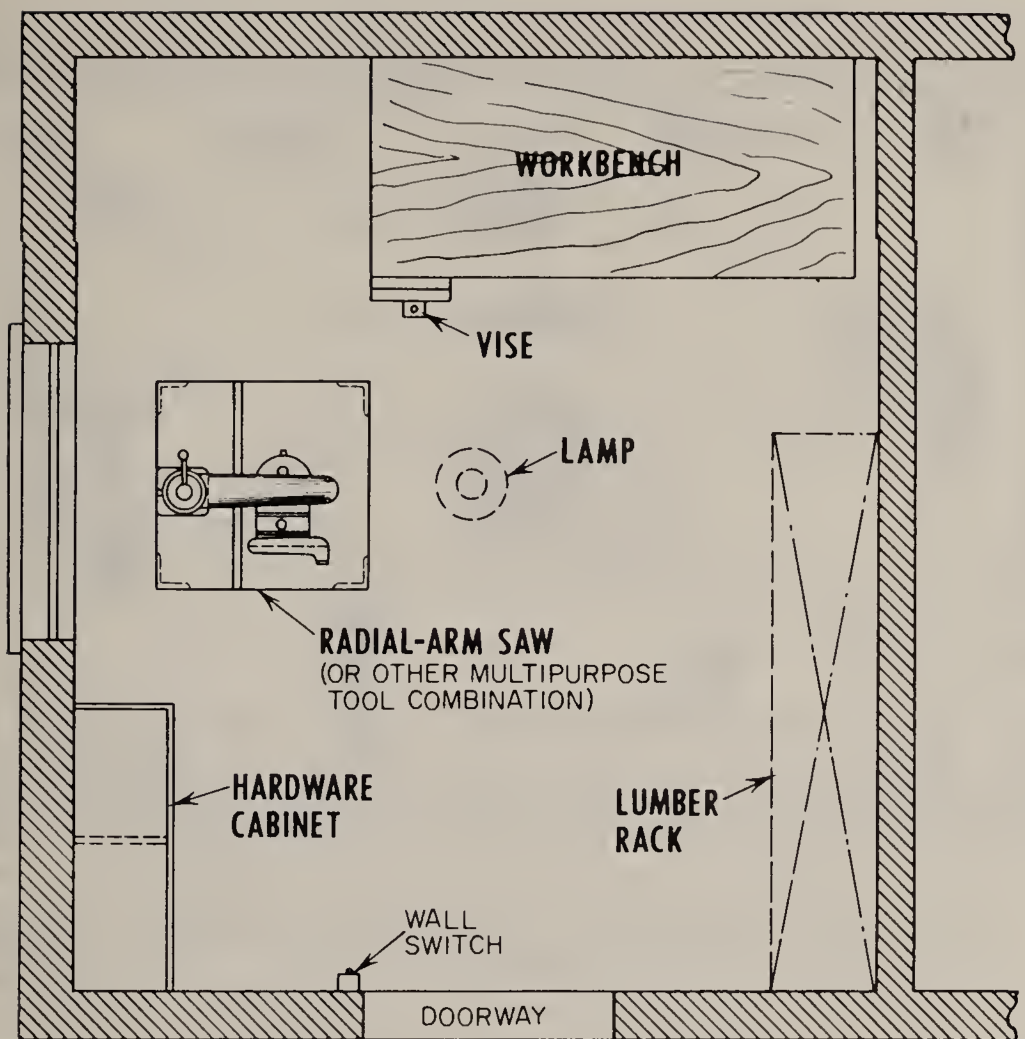


Fig. 6. Typical 8 × 10-foot basement workshop layout with one multipurpose power tool. Multipurpose power tools are frequently employed where the floor area and production requirements are limited.

The jigsaw should be placed in the fairway, but off center to avoid interference with nearby machines. The remainder of the power tools, namely the lathe and drill press, may be grouped against the wall, since in most operations the work does not generally project beyond these machines. In addition, ample workbench and counter space is provided along the walls for convenience and efficiency. Here the various hand tools, portable power tools and lumber may be arranged to suit individual preferences.

Maximum-Size Layout—In locations where there is ample space available and where a full complement of single-purpose power tools is needed, the various machines may be located as shown in Fig. 8. An arrangement of this type requires a minimum floor area of 13 × 30 feet or more.

With no premium on space, the problem actually resolves itself into how to locate the various power units for greater convenience

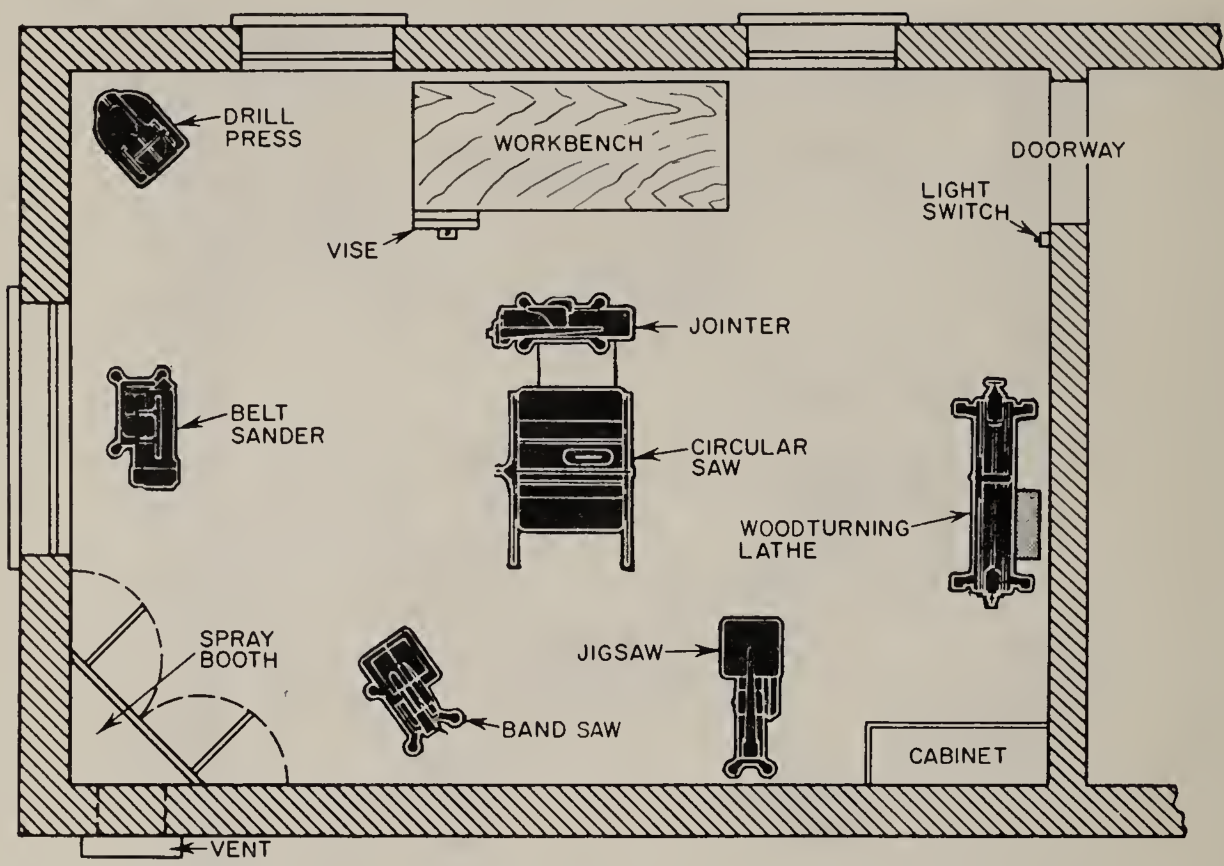


Fig. 7. Typical 13 × 18-foot basement workshop layout with seven basic single-purpose power tools.

and efficiency without unnecessary cramping of the working area. One area that may be set off from the rest is the finishing bench and its surroundings. In the spray-booth enclosure, articles may be left to dry after painting without fear of dust or smearing.

It should also be observed that with ample space, advantage should be taken of outside doorways for delivery and storage of lumber and supplies. By placing lumber storage near the door, it is possible to add supplies without interfering with the shop itself. In locations where an irregular floor area exists, a satisfactory power-tool layout may be obtained only if proper attention is paid to every known detail.

Sometimes it may aid in planning to lay out the available workshop area on a sheet of paper to a certain scale, such as 1:6, or 2 inches equals one foot of the actual floor dimensions. Using the same scale, make up a cardboard pattern of the machines to be installed, being careful to take down the maximum horizontal floor area covered by each.

By placing these machine patterns on the scaled floor plan, each in its contemplated position, and by moving them about until the

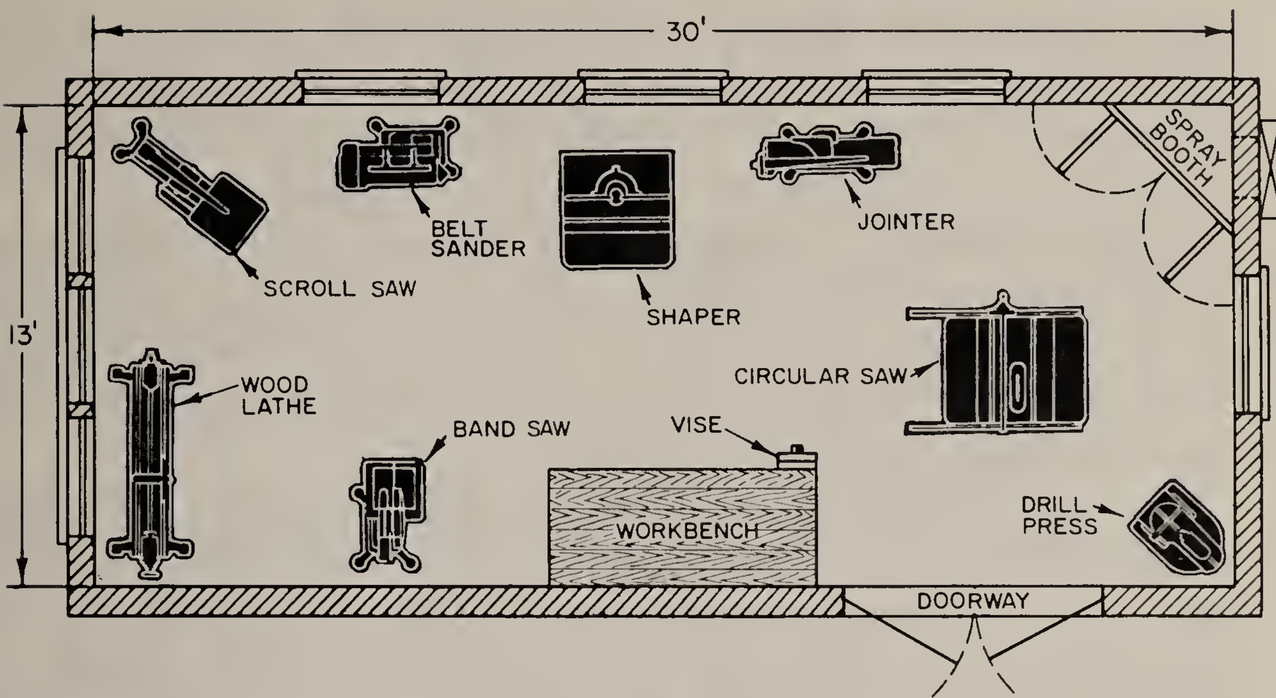


Fig. 8. Typical 13 × 30-foot above-ground workshop layout with eight single-purpose power tools. A shop of this size (containing nearly 400 square feet) will readily lend itself to production of large and medium size work. When erecting shops outside the house proper, the floor area required should be calculated to give the greatest amount of service. Thus, for example, the ideal all-round shop area for production work may be built in form of an "L" rather than in the form of a rectangle or square. Another point of importance is that doors and windows must be properly dimensioned for free unobstructed movement of work and materials as well as for lighting requirements.

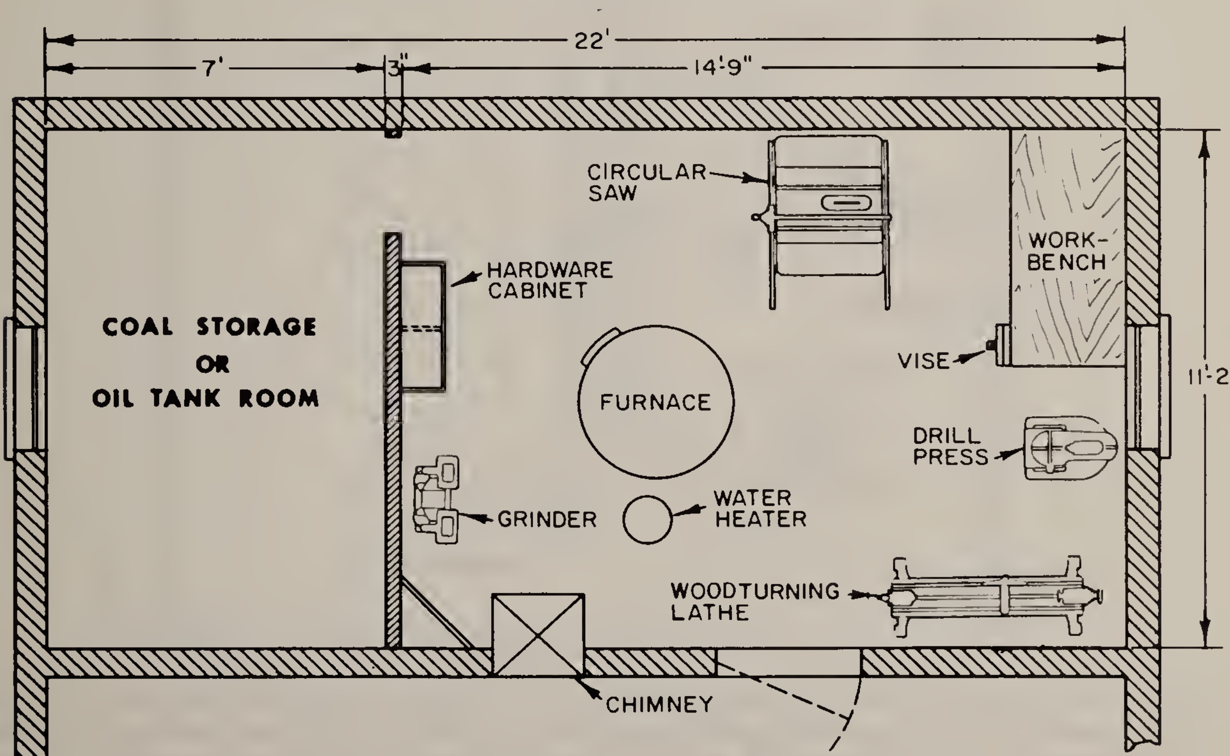


Fig. 9. Typical basement workshop with power tools placed in the furnace room of a divided basement. Because of the fact that the suitable basement space is in many instances occupied by laundry equipment, storage rooms and the like, consideration should be given to utilizing the furnace space for only a few of the most needed power tools.

most advantageous location of each power tool is found, a great deal of miscalculation and future trouble may be avoided. When this method is used, the available space between each machine as well as any other dimension may easily be found.

Miscellaneous Workshop Layout—In case of insufficient basement space, workshops are sometimes erected in the furnace room, as noted in Fig. 9. Here the various power tools are placed along the walls, with the workbench and circular saw against the far wall opposite the entrance door.

The coal bin may be used under certain conditions for lumber storage, particularly where conversion from coal to gas or oil has taken place. When contemplating workshop installation in the furnace side of the basement, it is important to fully establish the space requirements prior to the purchase of various power tools,

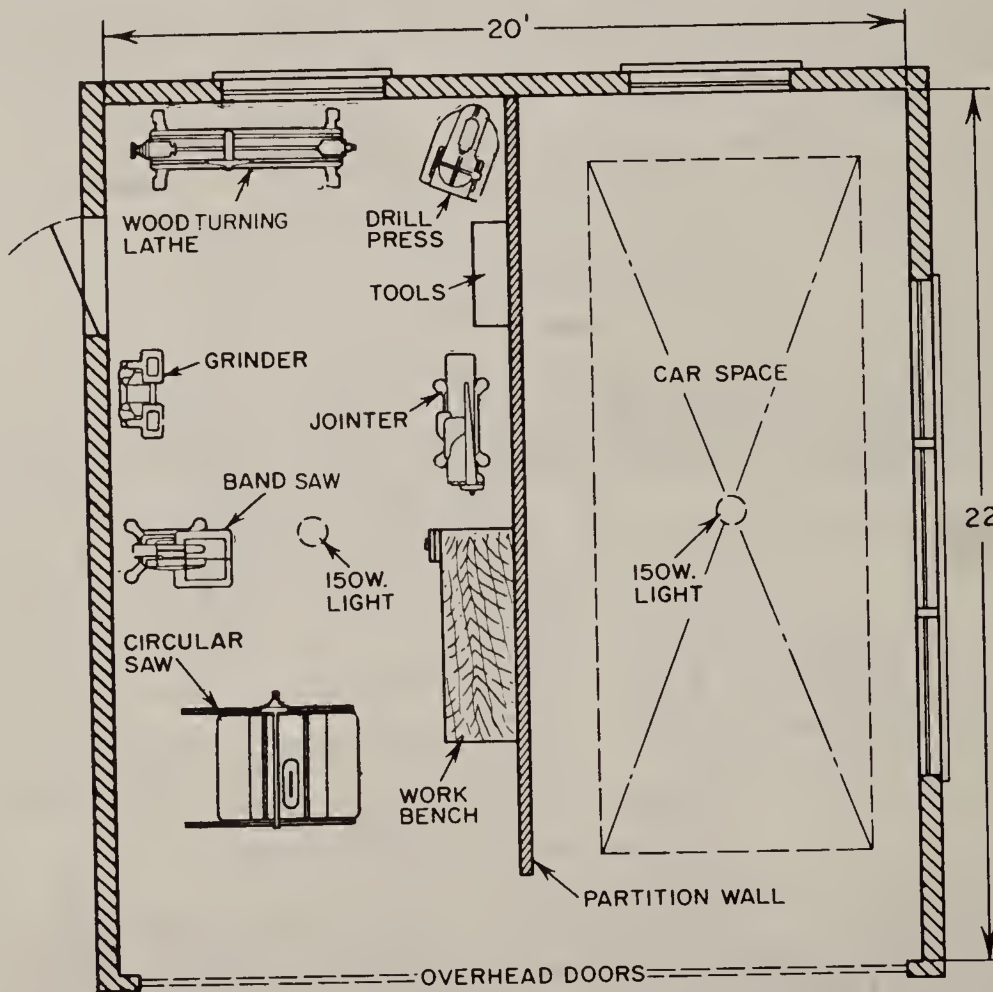


Fig. 10. A typical workshop housed in a divided two-car garage. By erecting a suitable wallboard partition enclosing the workshop area, an almost ideal space will be obtained. One advantage of having the workshop housed in this manner is the prevention of noise and vibrations from reaching the living area of the home, since the garage is usually located outside of the home proper. In locations where the available shop area is insufficient for proper placement of the necessary single-purpose tools, consideration should be given to the use of one or more multipurpose tools.

because in a great many instances a multipurpose tool would perhaps be more suitable. The placement of each tool should be carefully considered in order that a logical layout can be fully realized.

A typical workshop layout in a converted two-car garage is illustrated in Fig. 10. To obtain a suitable working area, however, it is suggested that a partition wall be erected to isolate the workshop from the car space proper. In cold climates a suitable gas or oil heater may be used to provide the necessary heat requirements. Since the average workshop activity, however, demands a great deal of body movement, temperature of about 60 to 65 degrees F. is usually sufficient.

A motor circuit of adequate capacity should be added to the existing electrical wiring system and under no conditions should the motor or motors be operated from the light circuits. The foregoing should always be observed regardless of the workshop location.

CHAPTER 2

The Workbench

In order to perform many of the numerous operations in the woodworking shop properly, a suitable workbench is essential. Broadly speaking the bench may be regarded as a tool, especially when considered with its various attachments for holding and clamping material during the numerous operations known as benchwork.

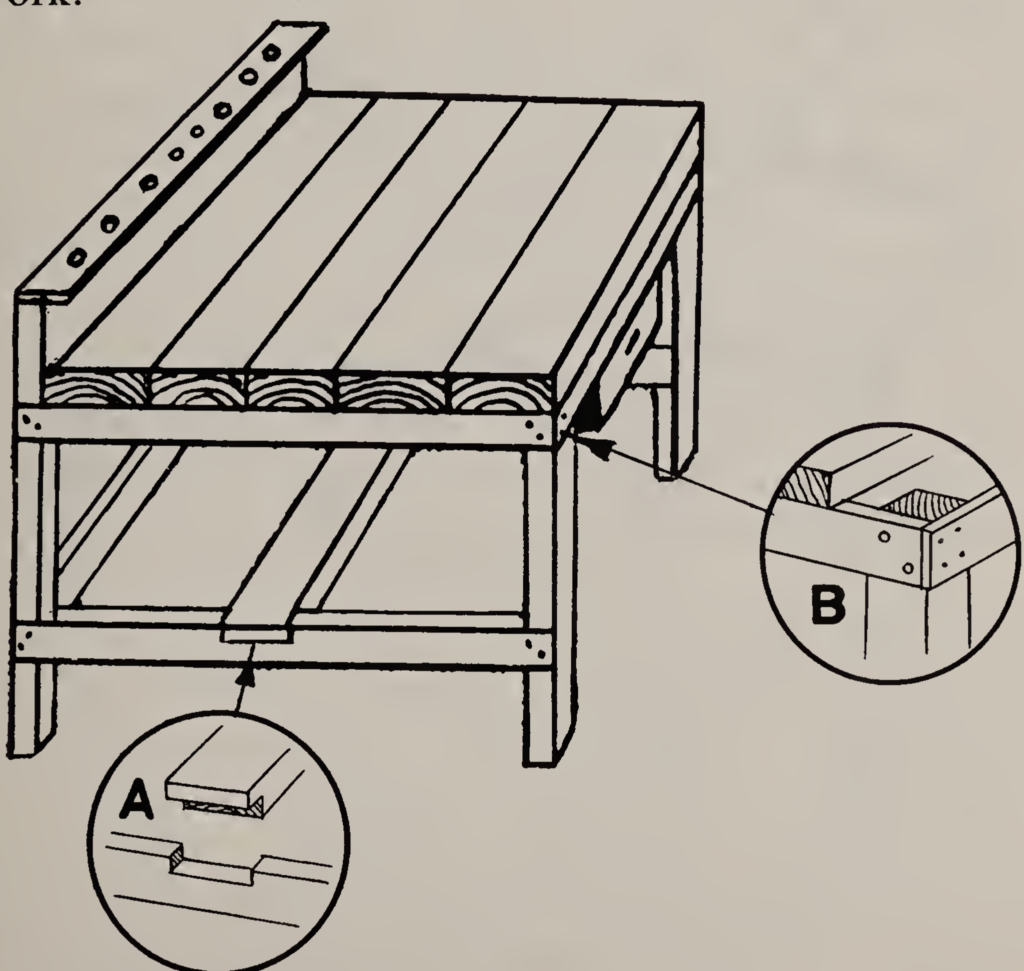
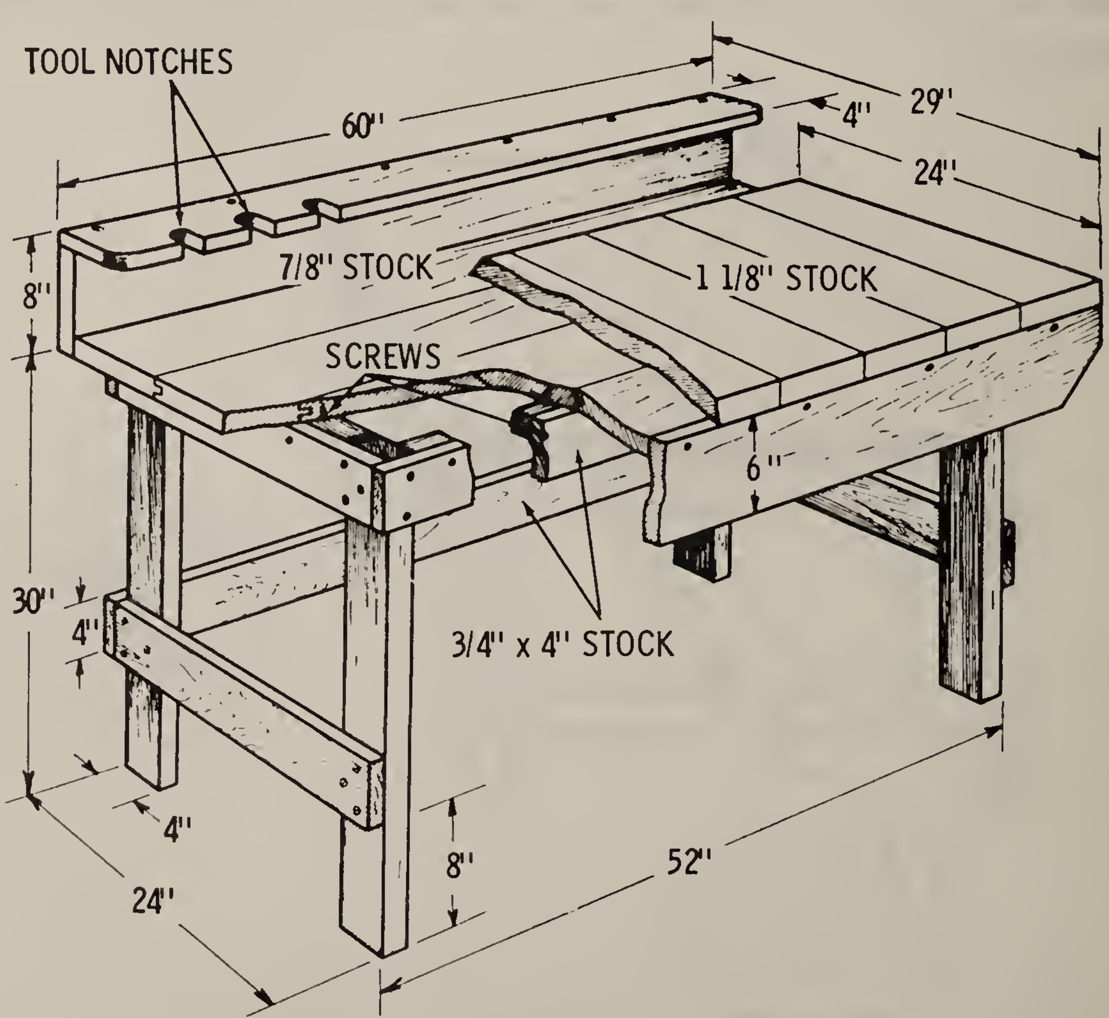


Fig. 1. Easy-to-make workbench showing general construction.

The Workbench

There is hardly a shop of any size that does not require a workbench, and it truly has been said that the workbench is the heart of the home workshop. Thus the workbench will be one of the first things needed. Substantial benches for all purposes are manufactured and for sale, but the wood craftsman can construct for himself the type of bench best suited to his requirement.

The height of the bench should be regulated to the character of the work to be done and to the height of the person who is to use it. In general, however, woodworking benches may vary from 32 inches to 36 inches in height, with about 33 inches being the most common. One of the simplest benches to build is a nailed or screwed structure with plain butt joints. A construction of this kind is shown in Fig. 1. The frame is stock shop lumber, the top being made from five pieces of 2 × 6 as shown. The length of the bench is 72 inches, the width is 30 inches and the height is 32 inches.



Courtesy The Delta Manufacturing Co.

Fig. 2. A well-made workbench of simple construction suitable for the small or medium-size shop.

The bench top should be set on a frame made of 2 × 4-inch lumber. Use hardwood lumber for the top, or, if desired, a masonite sheet can be placed over soft wood. Screw the top frame to the 2 × 4 legs (as shown in B). The lower cross braces and length braces should be notched to provide maximum strength (as shown in A).

A drawer can be added if desired; suggested size 28 in. × 30 in. × 6 in. Construct the drawer of ½-in. plywood. The drawer can be fitted to the bench in several ways: (1) by construction of a wooden frame of 1 × 2-inch stock to hold the drawer in place and (2) by suspending the drawer from angle irons—the set of angle irons on the drawer slide on the angle iron screwed to the underside of the top. The entire bench can be given two coats of clear finish. The end grain should be well filled to prevent checking.

Another easily built bench is illustrated in Fig. 2. The legs are 2 × 4 stock, and the remainder of the frame is 1 × 4 stock. Strips of 2 × 2 stock are used to fasten the top unit and frame together. To increase the rigidity and sturdiness of the workbench, the top has been constructed of two layers—one of 1-in. stock tongue-and-grooved, covered by a top layer of 1⅛-in. stock. Lumber used should all be straight, high-grade, kiln-dried birch or pine. The top is hardwood, of which maple is best.

A third workbench of more elaborate construction is illustrated in Fig. 3. The frame is 2 × 4 lumber, while the ends are constructed as panels and joined together with 2 × 4 rails. The back is covered with a plywood panel rabbeted in the same manner as the ends. The partitions are screwed in place with half-lap joints at the rail intersections. Drawer, drawer runners, and drawer guides are shown in the detail drawing (Fig. 4).

The bench top is built up of 1¾-in. × 2¼-in. hard-maple strips, or equal. The construction, however, will be similar, regardless of the size and type of hardwood used. The strips are planed smooth for a good glue joint, and holes are drilled for the bolts. Glue and bolt the top together and allow to dry. Dowel the tool tray and backboard to the top. Bolt the top to the frame with lag screws or carriage bolts, with heads countersunk as shown.

Workbench Attachments—Numerous devices are used with workbenches to facilitate the operations to be performed. A few of these devices or attachments are:

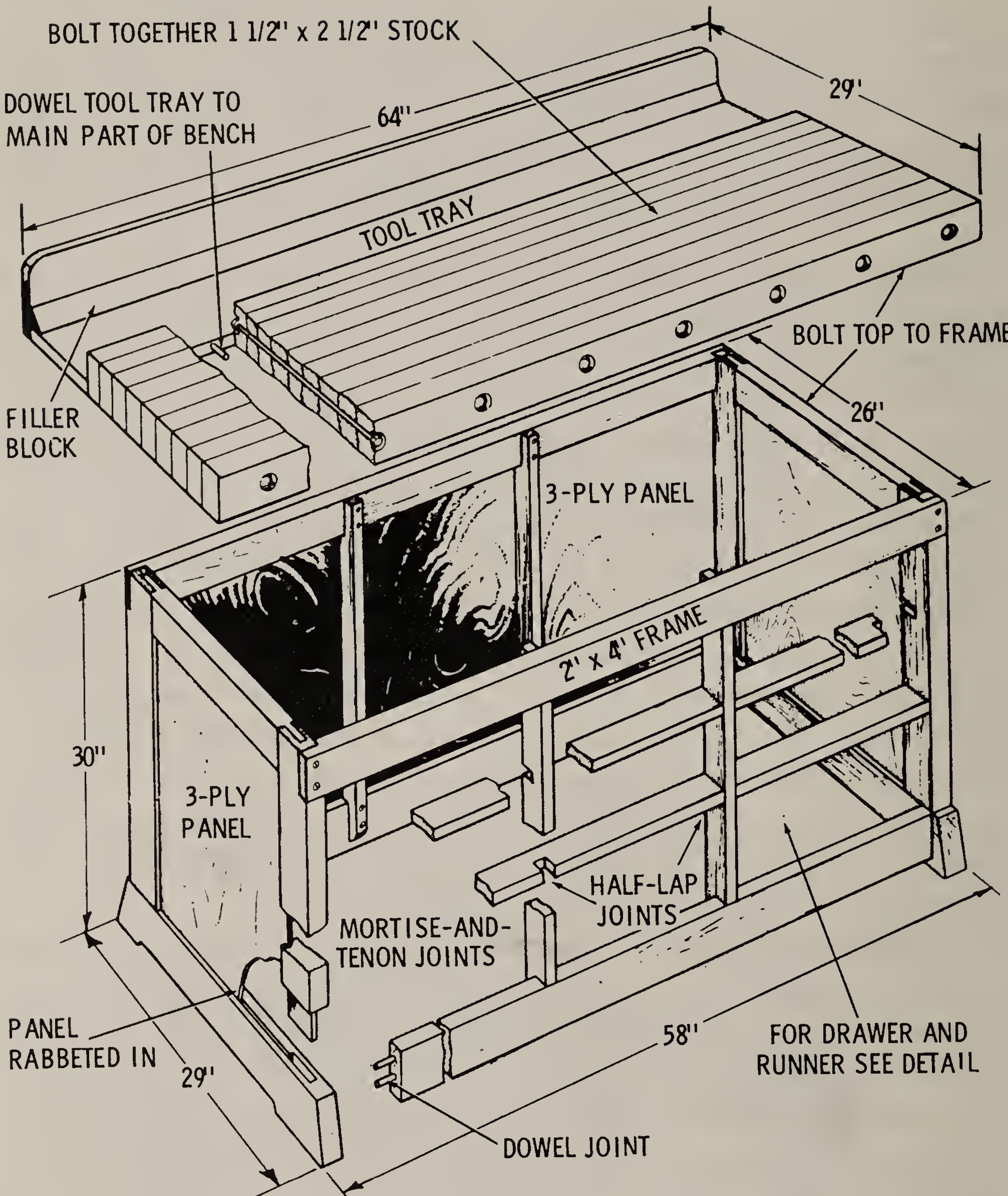


Fig. 3. Construction details of a workbench designed for appearance as well as convenience. The 2 × 4-in. rails, corner posts and base members provide for a sturdy bench which will give many years of satisfactory service.

1. Vises
2. Support pegs
3. Stops
4. Hooks

Mounting a Vise—Although directions for installation often accompany a vise, it is advisable to plan the installation procedure

carefully before proceeding. The most useful type of vise for the home workshop is one which may be used for either wood or metal. The flush-type vise as illustrated in Fig. 5 is designed for wood only.

It is best to fasten with bolts rather than with screws, whenever possible, because bolts permit the maximum strain to be placed on the vise without ripping it off the bench. Where conditions require, it is good practice to install a woodworking vise at the left end of the bench top, as shown in Fig. 5, and a machinists' vise at the other end. A set of copper jaw inserts should be made for the vise to protect soft work which otherwise may be damaged due to pressure of the jaws.

Support Pegs—The function of the woodworking vise is to hold the wood secure from all movements while being worked with a plane or chisel. In these operations the work receives a pressure which tends to rotate it in the vise jaws, the latter acting as a pivot.

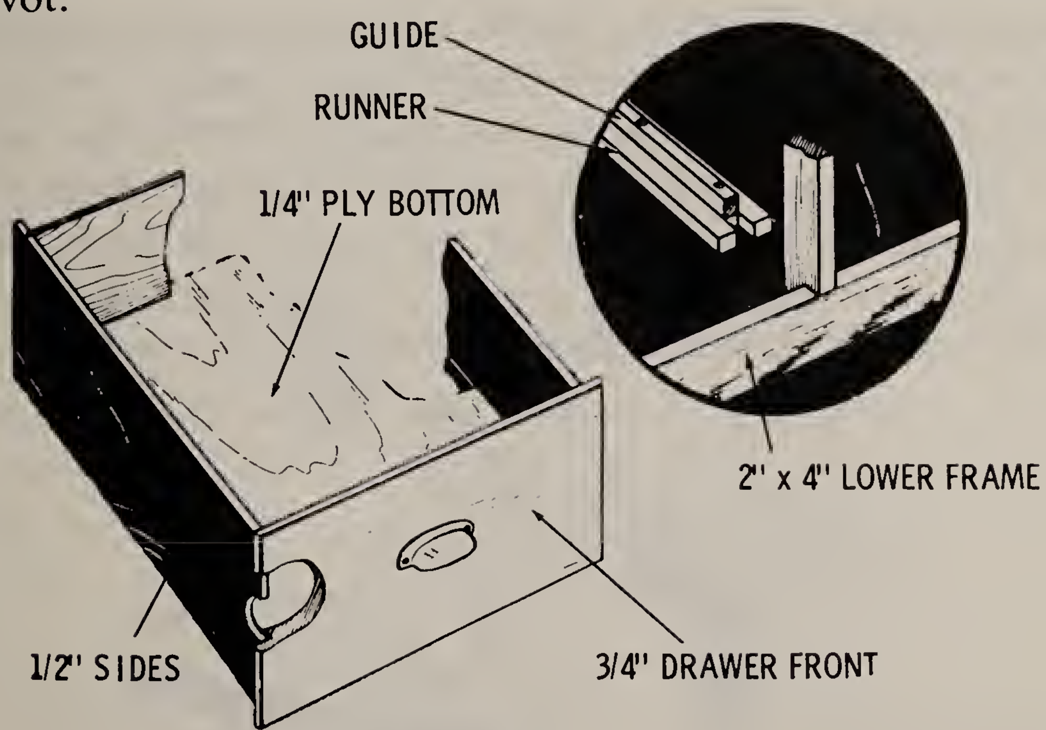


Fig. 4. Drawer details for workbench drawer. The guides should be properly fastened in the exact centers of the drawers to prevent jamming.

In the case of a long board the leverage becomes very great when a downward pressure is applied to the far end of the board, requiring the vise to be screwed up firmly to prevent any movement. To avoid this, the bench should be provided with supporting pegs which carry the weight of the board and prevent it from slipping when a downward pressure is applied.

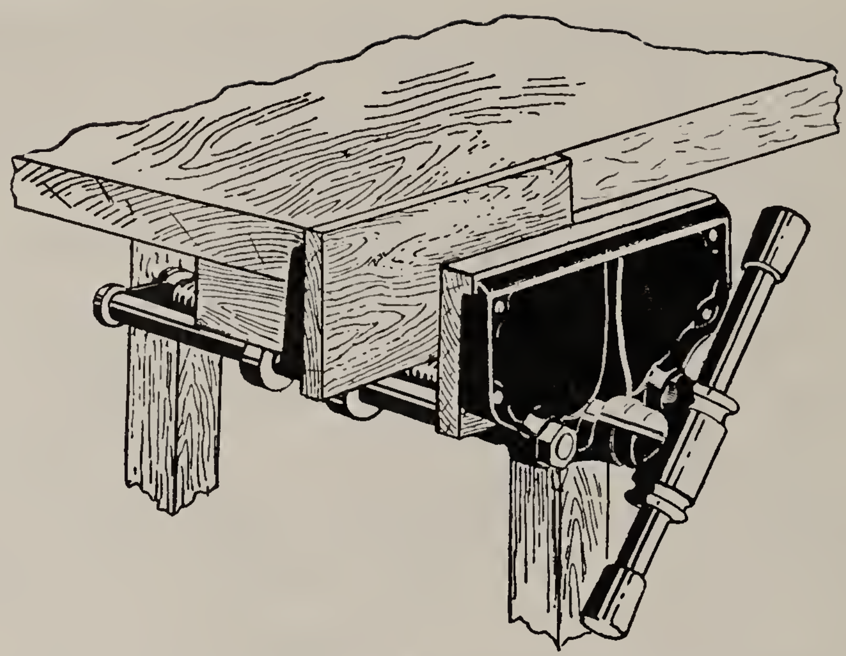


Fig. 5. Method of attaching vise to the workbench. In construction, the inner jaw is fastened to the bench and supports a fixed nut in which the screw rotates. This screw controls the outer jaw which has attached to it two rods working in sleeves and keeping the jaws parallel for all positions of travel.

Bench Stops—These are devices intended to prevent any longitudinal movement of the work while being tooled, as in the case of a board being planed. As usually constructed for this purpose, a stop consists of a metal casting designed to project slightly above the surface of the bench so that it can engage the work piece. A screw adjustment controls the degree of projection and allows the stop to be retracted flush with the bench top when not in use.

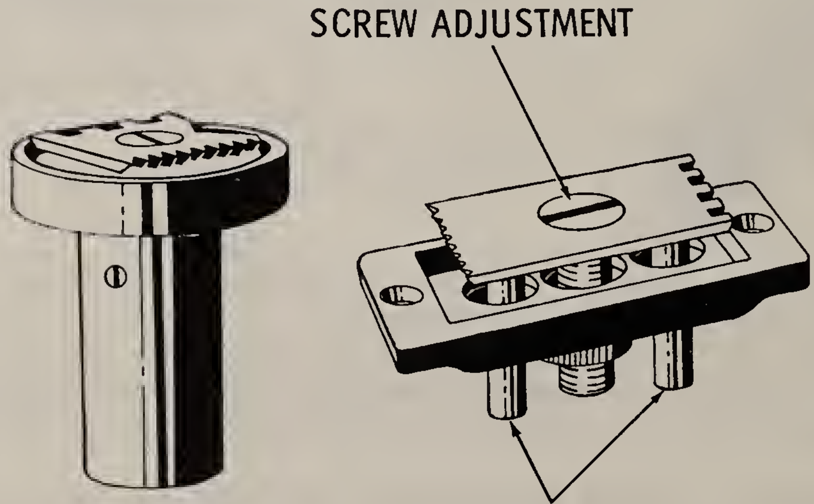


Fig. 6. Round and square forms of bench stop. These adjust by a center screw from flush to as high as required for the work being planed. The round bench stop is fitted by boring a hole the diameter of the stop with an extension bit and a deeper center with the size of the bit required. The rectangular bench stop is shallow and should be mortised in flush with bench top.

Fig. 6 shows two forms of bench stops. A bench stop may also be made of a piece of 2 × 2 stock projecting through a mortise in the top of the bench. This kind of stop is suitable for use with the bench hook; for the main stop, however, it is better to have some form of iron fitting such as is shown in Fig. 6.

Bench Hooks—This is virtually a movable stop that can be used at right angles to the front of the bench. It serves many purposes for holding and putting work together. When it is desired to saw off a piece of stock, the bench hook is placed on the bench, one shoulder set against the edge of the bench as noted in Fig. 7, while the upper shoulder serves as a stop for the work while sawing.

Tool Cabinets—These are an integral part of any workshop and are used to provide storage space for tools, hardware, and parts used in the shop. Tool cabinets in suitable sizes can be purchased in numerous hardware stores but are rather simple to make, as shown in Fig. 8A, B, and C.

The base unit is made from stock of 1 × 12 boards, with the sides grooved to take the shelves as illustrated. A plywood back can be added by rabbeting the sides or can be simply butted between

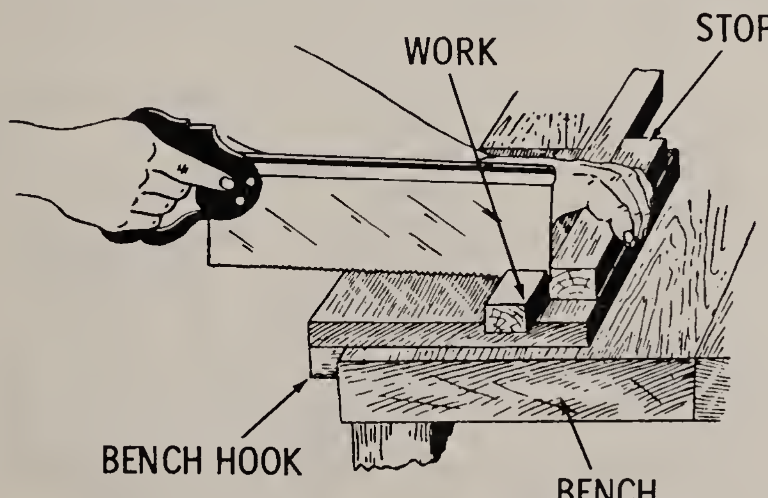


Fig. 7. Typical bench hook and methods of use when sawing to size with back saw. The bench hook is used for a variety of operations such as odd sawing and chiseling, and serves also to prevent the workbench from being marred by such operations.

the two sides. Fig. 8B shows a bench-height unit added, with the top slightly overhanging.

Further additions and modifications illustrate cabinet construction by the add-a-unit method. If desired, the shelves can be installed on cleats nailed to the sides rather than by means of the

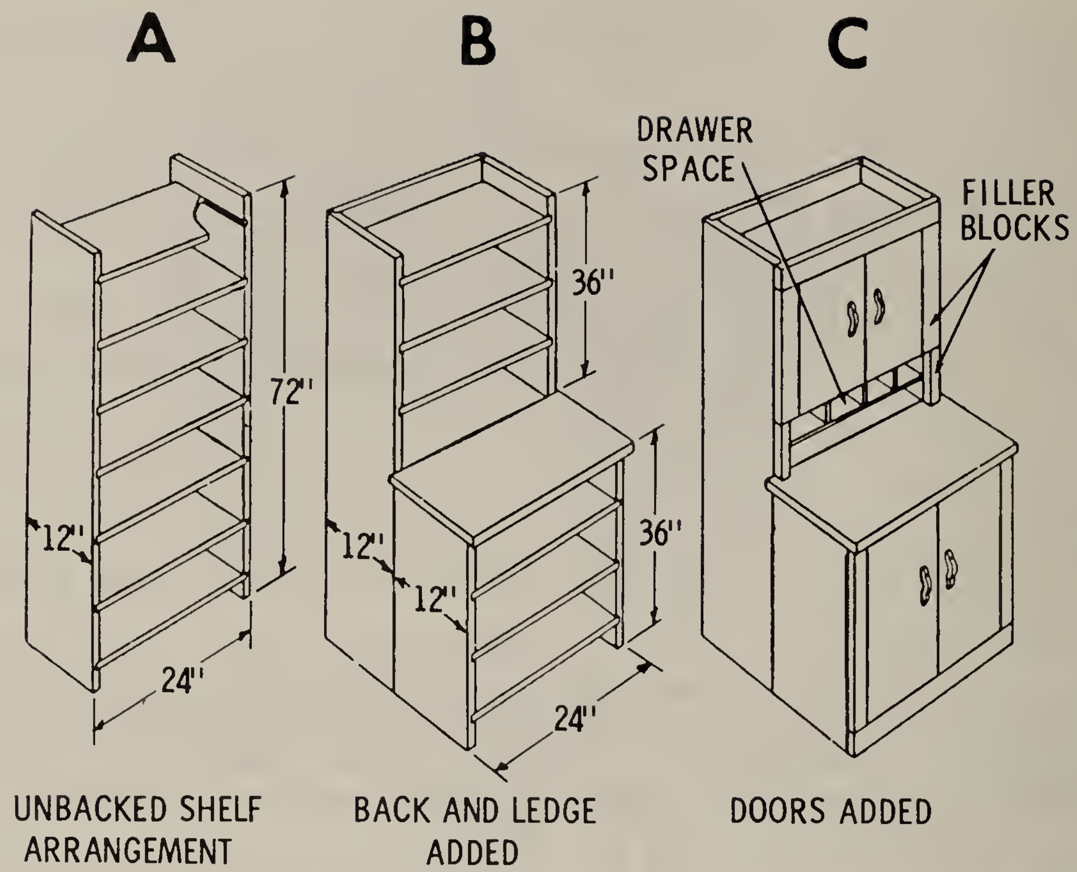


Fig. 8. Construction of typical tool cabinet in various stages of completion.

housed joints shown. A cabinet of this type can be quite attractive if made of white pine, finished with two coats of clear finish.

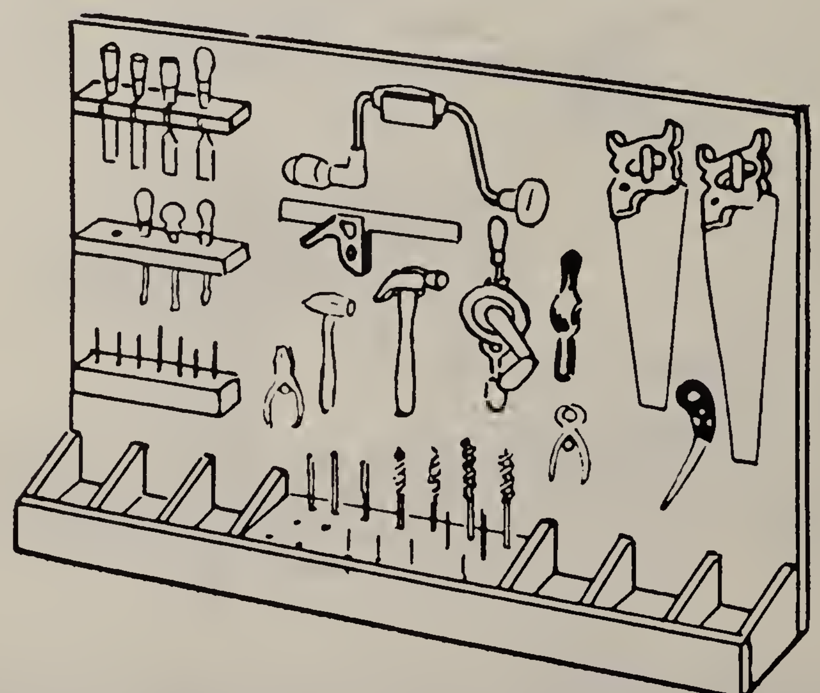


Fig. 9. Typical tool panel showing arrangement of tools.

Tool Panels—These, as the name implies, provide assigned positions for each tool and will induce the craftsman to keep his

shop orderly by putting the tools back where they belong after each use.

A place for everything and everything in its place, should be the aim of every home workshop operator. If it is assumed that a tool collection is available for mounting, the best system is to plan and fit the various units properly before the panel is put in place. The simplest tool mounting is by means of a pair of nails,

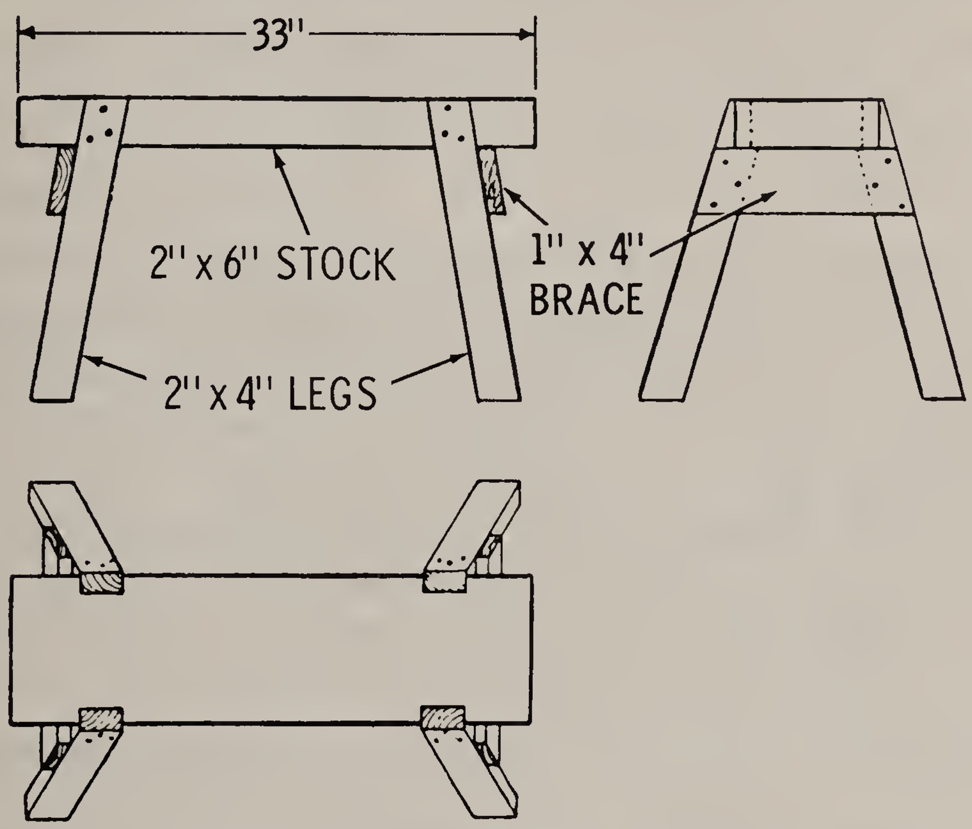


Fig. 10. Construction of a sawhorse suitable for heavy work.

although a neater and more satisfactory method is to use wood or metal dowels. The usual practice is to have one or two racks with holes or slots, while the design of the rest of the panel depends upon the number of tools available and their size and frequency of use.

Prior to fastening the necessary dowels and racks, the panel should be sanded smooth and given a coat or two of shellac or paint. This will give the panel a neat and clean appearance. A suitable molding nailed to the edges of the panel will add to the workmanlike appearance of the job. Tool panels of this type are usually made of fir plywood and must be strong enough to support the combined weight of the tools mounted upon it. Several sizes of perforated hardboard are also available and are widely used for

tool panels. They are attractive and relatively inexpensive, and provide very convenient access to tools.

Sawhorses—These are used in various ways to support lumber or other materials when the work is of such large dimensions that it cannot be supported conveniently by the workbench. Sawhorses are particularly useful when marking and sawing long pieces of lumber, and they can also be used for heavier mortising, the worker sitting on top of the work to provide stability.

Sawhorses, even when comparatively light in weight, should be sturdy and well braced. A sawhorse that shakes and is in danger of collapsing is a hazard to use. Lightweight sawhorses are 3 or 4 ft. in length, of 2 × 4 or 2 × 6 stock for the crossbeam, and have a pair of legs of 1 × 4 or 2 × 4 stock at each end, depending upon the weight of the work. The height of the horses should be made to suit individual conditions and may vary from about 24 inches to 36 inches. Legs are usually given an outward slant to make the sawhorse more difficult to upset.

Plans for the construction of heavyweight sawhorses are given in Fig. 10. The crossbeam consists of 2 × 6 stock cut to a length of 2 ft. 9 inches, whereas the legs are of 2 × 4 stock. The 1 × 4 braces are placed as indicated to provide additional strength.

Collapsible Sawhorses—Since the space requirement for storing numerous sawhorses when not in use may become somewhat of a problem, a great many shops make use of the collapsible-type sawhorse, which may easily be disassembled or taken apart for storage.

CHAPTER 3

Hand Tools and Their Use

The success of any workshop operation depends upon having a sufficient quantity of hand tools of good quality. In their selection it is important to buy only the highest quality tools. Select carefully from standard makes, examining them to make sure there are no visible defects. The temper of steel may be discovered only by use, and any defect in the best grades of tools is usually made good upon complaint to the dealer, hence buy only the best grades. Hand tools may be classified with respect to their use as:

1. Marking and measuring tools
2. Guiding and testing tools
3. Holding tools
4. Sharp-edged cutting tools
5. Toothed cutting tools
6. Boring tools
7. Fastening tools
8. Miscellaneous shop tools, etc.

Most hand tools are actually purchased one or more at a time, and are seldom bought in quantity, since the average workshop is normally well stocked with hammers, saws and most other household items.

The type and number of hand tools required depend upon individual preferences and the work to be done, although a good basic list will comprise about 30 essential tools such as enumerated in Figs. 1 and 2. While the list of hand tools may be increased to

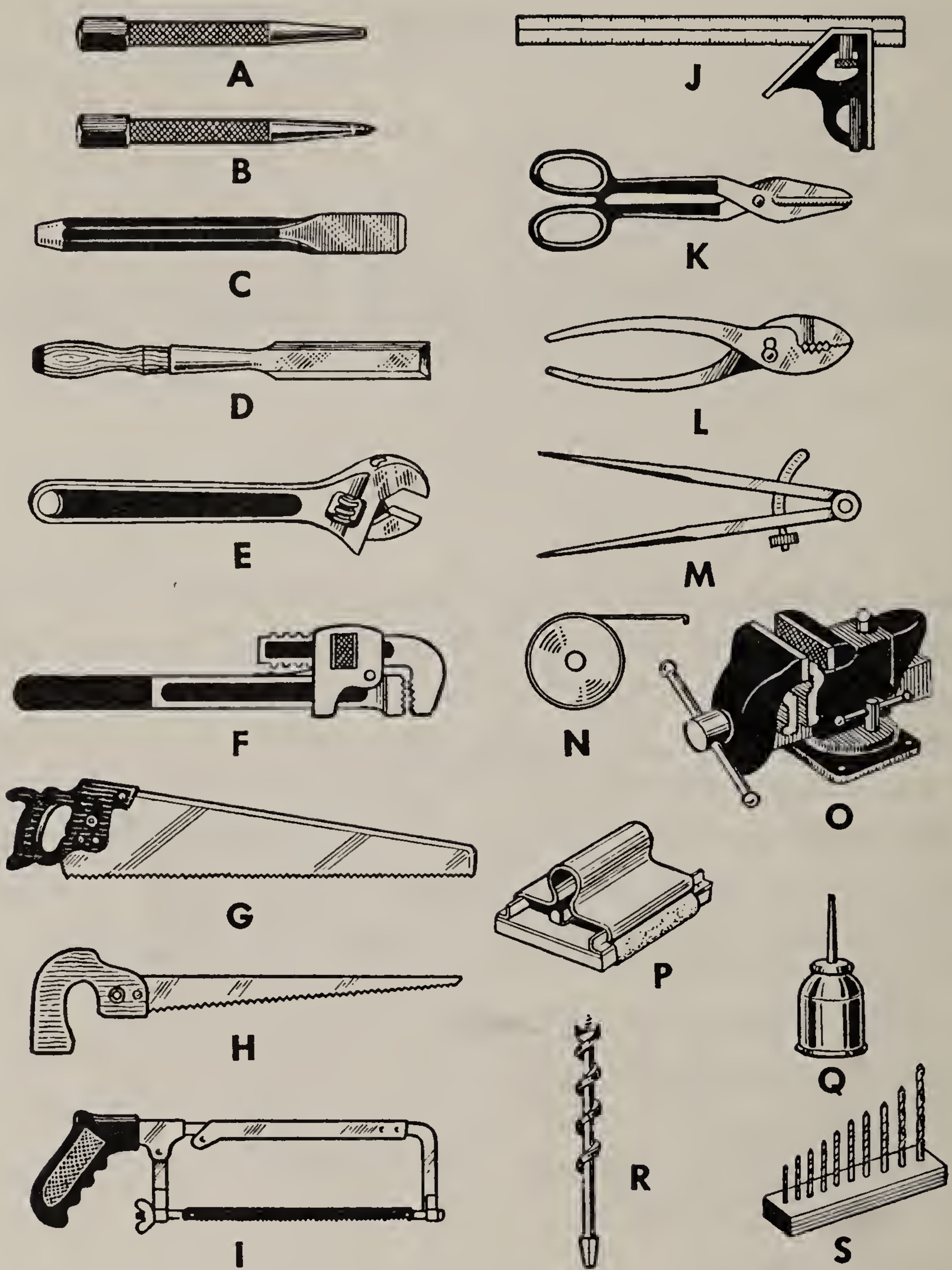


Fig. 1. Typical hand tools used in the average workshop. In the illustration A represents nailset; B, center punch; C, cold chisel; D, wood chisel; E, adjustable wrench; F, Stillson wrench; G, handsaw; H, compass saw; I, hack saw; J, combination square; K, tin snips; L, combination pliers; M, dividers; N, pull-push steel rule; O, machinists' vise; P, sandpaper holder; Q, oilcan; R, auger bit; S, twist-drill set.

a very large number, most ordinary woodworking projects can be performed with a strictly limited number of tools. There are two rules bearing on the selection of hand tools, as follows:

1. Buy tools only as they are needed, and
2. Buy the highest quality

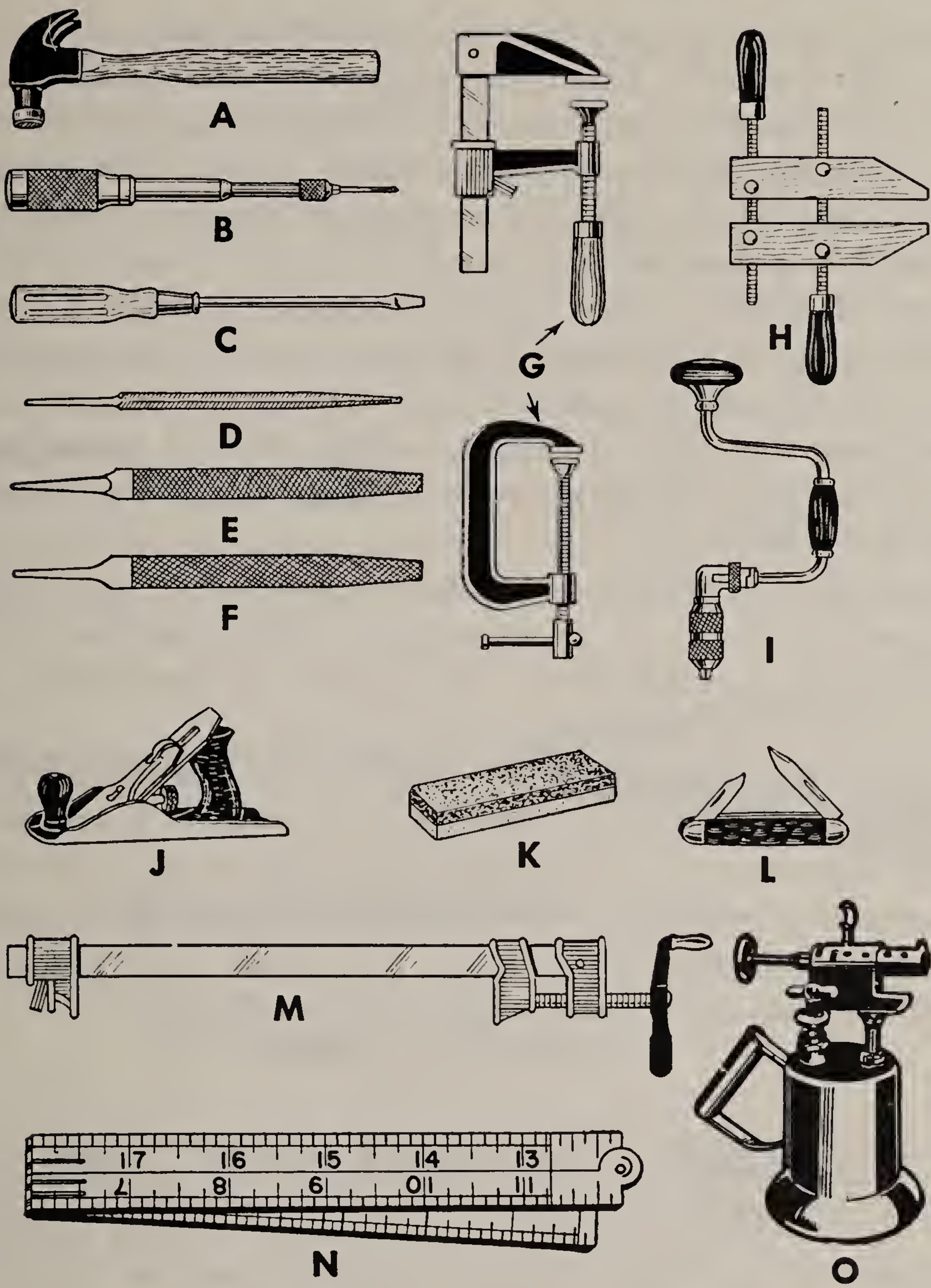


Fig. 2. Hand tools continued. A. claw hammer; B, automatic push drill; C, screwdriver; D, slim-taper file; E, bastard file; F, rasp; G, clamps; H, hand screw; I, bit brace; J, jack plane; K, combination oilstone; L, pocketknife; M, long bar clamp; N, boxwood rule; O, blowtorch.

From the foregoing it follows that there is no particular need to purchase kits of tools enclosed and boxed, because such kits may contain numerous tools for which there is no immediate use.

Storage of Tools—The proper storage of hand tools is a problem needing individual solution. Tool racks on walls around the workshop are satisfactory to many craftsmen, although dust accumulates rather rapidly when this method is used.

Drawer space should preferably be utilized, so that each tool may be returned to its individual place and kept in good condition. The old-fashioned tool chest has numerous adherents, but is chiefly valuable because of its portability. Most craftsmen prefer to keep some tools in special dust-tight wall cabinets while others are stored in a workbench drawer.

Care of Tools—Since a good set of tools represents a considerable investment, a great deal of care and proper maintenance is the best insurance against failure and waste. It must also be remembered that since a craftsman is most often known by his tools, every effort should be made to keep the tools as clean and bright as when new.

The edges of cutting tools should always be kept properly sharpened and free from nicks and rust. Occasional use of a few drops of light oil, wiped off on a soft cloth, will prevent rust when the tools are not in daily use.

Familiarity with hand tools is of primary importance for the wood craftsman, since even the simplest routine job requires the use of tools. Because the proper use of hand tools is one of the fundamental requirements upon which every successful operation depends, a considerable amount of text matter has been devoted to these all-important basic steps and procedures.

MARKING AND MEASURING TOOLS

In woodworking and joinery, much depends upon accuracy in the layout of the work. The term *layout* means the operation of marking the work with pencil or scriber so that the various centers and working lines will be set off in their proper relationship. These lines are followed in cutting and other tooling operations necessary to bring the work to its final form. Various tools are used in making the layout, ranging all the way from a simple kit consisting of square, hammer and punch to quite elaborate instruments essential for very exacting work.

The Pencil—In laying out holes on wood, the layout mark, usually made with an ordinary pencil, must be made with care in order to locate its exact position. When a pencil is used for marking, the best results are obtained by rotating the pencil between the

fingers while drawing the lines so as to retain the conical shape given the lead in sharpening.

The Scriber—While the ordinary pencil makes a very clear mark on wood, the markings on metal are commonly made by a scratch awl or scriber. The scriber is a tool of extreme precision and while intended especially for machinists, it should be a part of the tool kit of any woodworker as well. A scriber, as shown in Fig. 3, is a hardened steel tool with a sharp point designed to mark very fine lines.

Compasses and Dividers—A compass is primarily an instrument used for describing circles or arcs by scribing. It consists of two pointed legs hinged firmly by a rivet so as to remain set in any position. The usual form of woodworker's compass is shown in

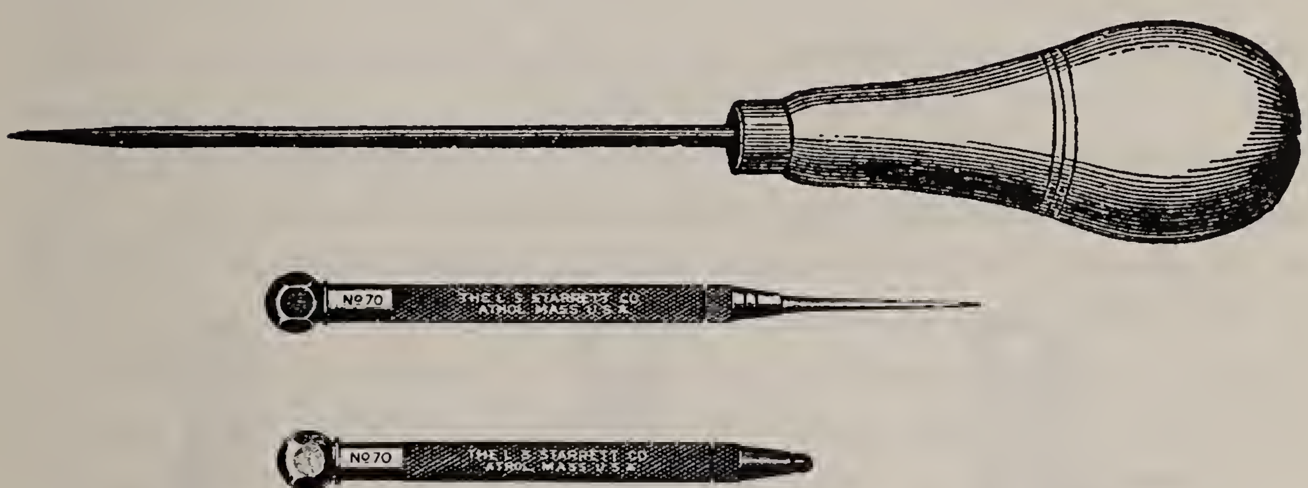


Fig. 3. Ordinary scratch awl and pocket scriber. A scriber of the type shown is reversible, telescoping into the stock, and is held by a slight turn of the chuck so that it is always as safe to carry in the pocket as a penknife.

Fig. 4A. It should not be used instead of dividers for dividing an arc or line into a number of equal divisions, because it is not a tool of precision, but is used mainly for describing arcs and circles.

The difference between dividers and compasses is that the dividers are provided with a quadrantal wing projecting from one of the two hinged legs through a slot in the other. A setscrew on the slotted leg enables the instrument to be securely locked to the approximate dimension and adjusted with precision to the exact dimension by a thumbscrew at the other end of the wing. A spring pressing against the wing holds the leg firmly against the screw. Its

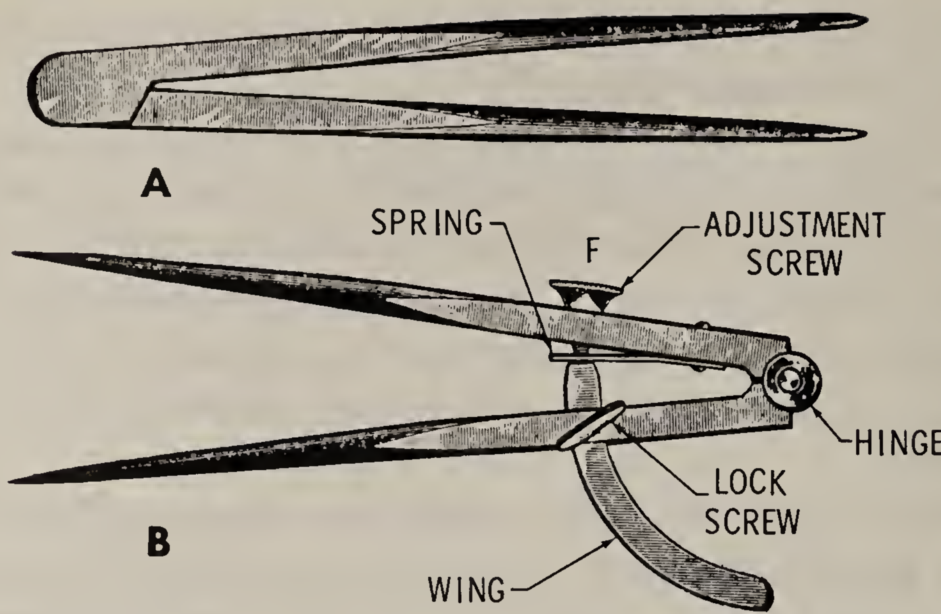


Fig. 4. Typical compass and divider used in woodworking shops. (A) compass and (B) divider.

general appearance is shown in Fig. 4B. Because of the wing the tool is frequently called a wing divider.

Inside, Outside, and Hermaphrodite Calipers—The inside, outside, and hermaphrodite calipers (Fig. 5) are useful for many small measurements. Outside calipers measure the diameter of

Fig. 5. Typical inside, outside, and hermaphrodite calipers.

small tubular objects such as rods, tubing, bolts and the like, whereas inside calipers are used for taking inside measurements of chambered cavities, flanges, etc., without losing the measurement of the size calibrated. Fig. 5 to 8 show typical calipers and methods of taking measurements.

To those who are not familiar with the use of calipers, a word of caution may not be out of place. Calipers should never be used

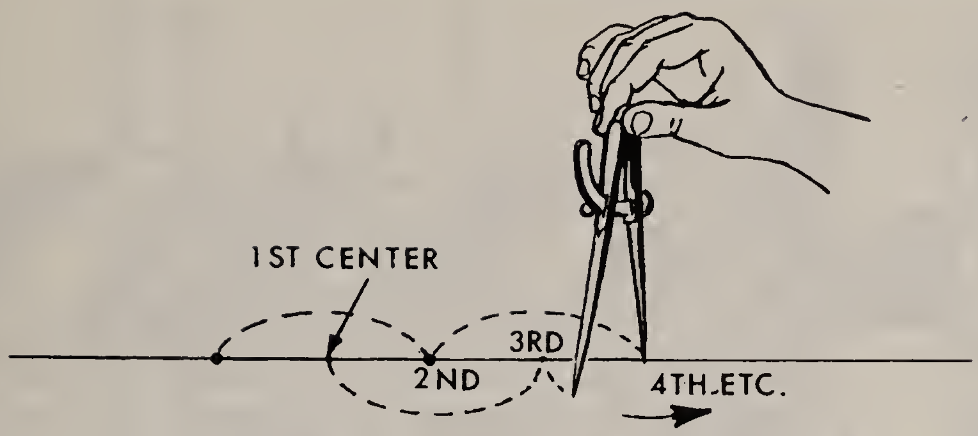


Fig. 6. Dividers used to step off a number of identical distances on a straight line.

on work while it is revolving in the lathe or in any other machine, because if one contact of the caliper is placed against the work, the other is likely to be drawn over the work by friction of the moving surfaces. Only slight force is necessary to spring the legs of a caliper, so that measurements taken from moving pieces are never accurate, and are in most instances misleading.

Pocket-Slide Calipers—These calipers as noted in Figs. 7 and 8 are provided with scales on the slide by means of which measurements may be read directly on the tool without transfer to a rule for size determination. Another valuable feature of the caliper is that it may be locked by the thumb of the same hand in which the tool is held, thus preventing a movement of the slide after the measurement has been obtained.

Trammels—This tool is used for scribing large circles and for taking exact measurements too large for the tools previously described. It consists essentially of a wooden beam upon which

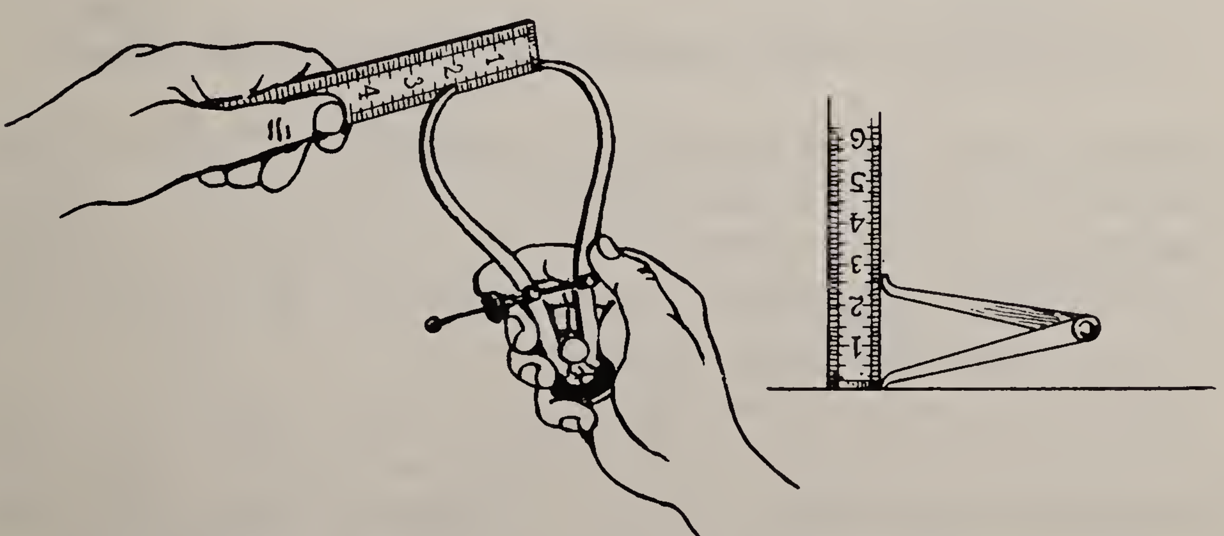


Fig. 7. Method of setting calipers. To set calipers hold one leg on end of rule and the other on measuring line.

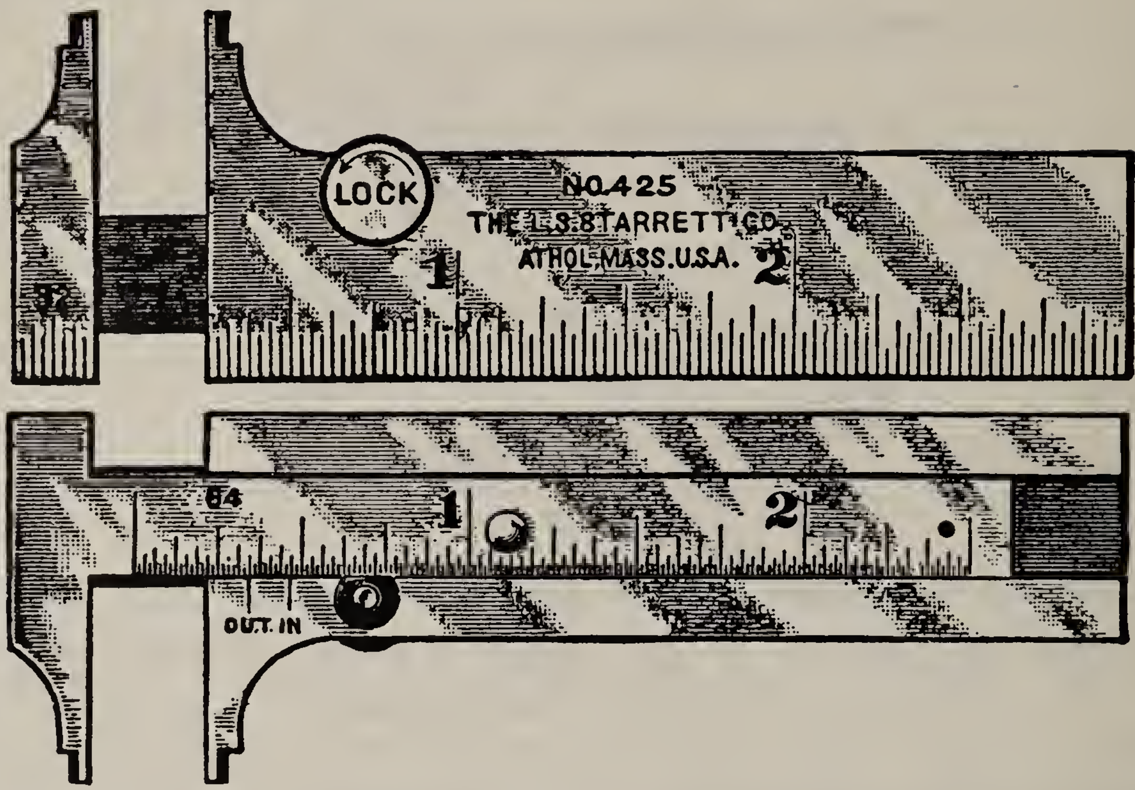


Fig. 8. Typical pocket-slide caliper showing arrangement of scales.

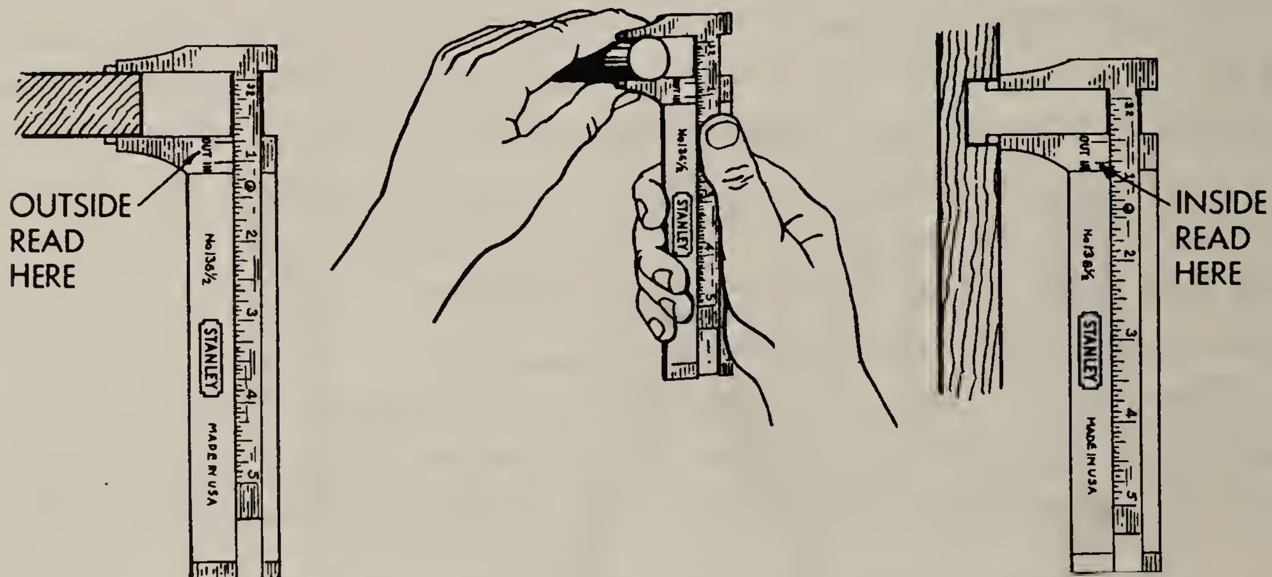


Fig. 9. Method of taking measurements with pocket-slide caliper.

trammel points or legs are fastened by means of a sliding pair of trammel heads as indicated in Fig. 10. By using the special trammel points shown or by substituting a pencil for one of the steel points, it is possible to scribe a circle from the center of any hole up to several inches in diameter.

In layout work, after having scribed a line with one of the marking tools previously described, the next step is usually to measure off on the scribed line a given distance. This is done with a suitable measuring tool. There are numerous kinds of rules used for measuring tools.

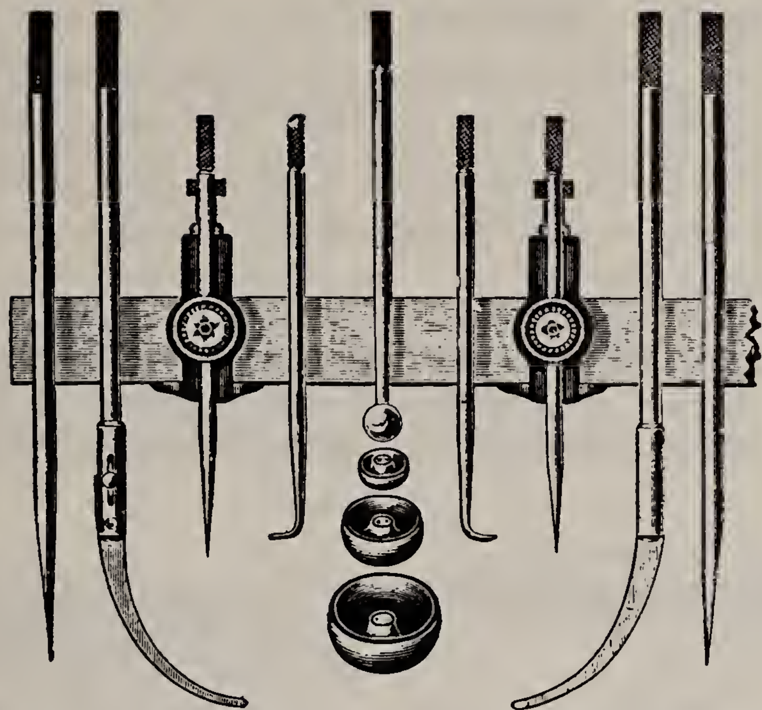


Fig. 10. Trammel used for laying out, scribing, and measuring. Any one of the trammel points can be removed and a pencil substituted in its place. Adjustable spring dividers are used in numerous applications where dimensions are such that ordinary tools cannot be employed.

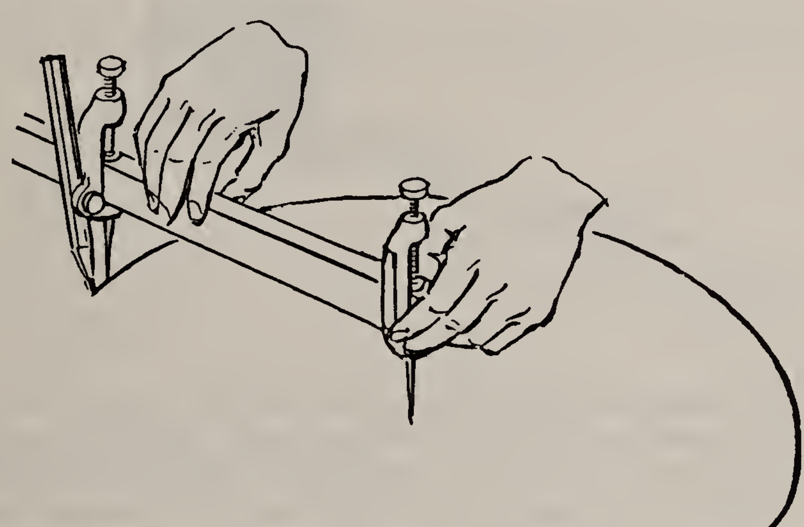


Fig. 11. Use of adjustable trammel for work on large area.

Folding Rule—The two-foot–four-fold rule is the most familiar form of folding rule (Fig. 12C) and can be folded into a short length for convenience in carrying. Distances up to two feet are measured with this type of rule. It is graduated in inches, halves, quarters, eighths, and sixteenths of an inch. The folding rule is made of boxwood, because this wood is affected least by climatic conditions.

The Flexible Steel Rule—A rule of this type is shown in Fig. 12D. Because it may be easily extended and coiled back into its case, it has found extensive use in woodworking shops.

The Single-Bar Marking Gauge—A single-bar marking gauge is used for making a single mark as for sawing. It consists of a bar having a scriber at one end and provided with a scale graduated in inches and sixteenths. The bar passes through a movable head that may be clamped on at any distance from the scriber point as shown in Fig. 13.

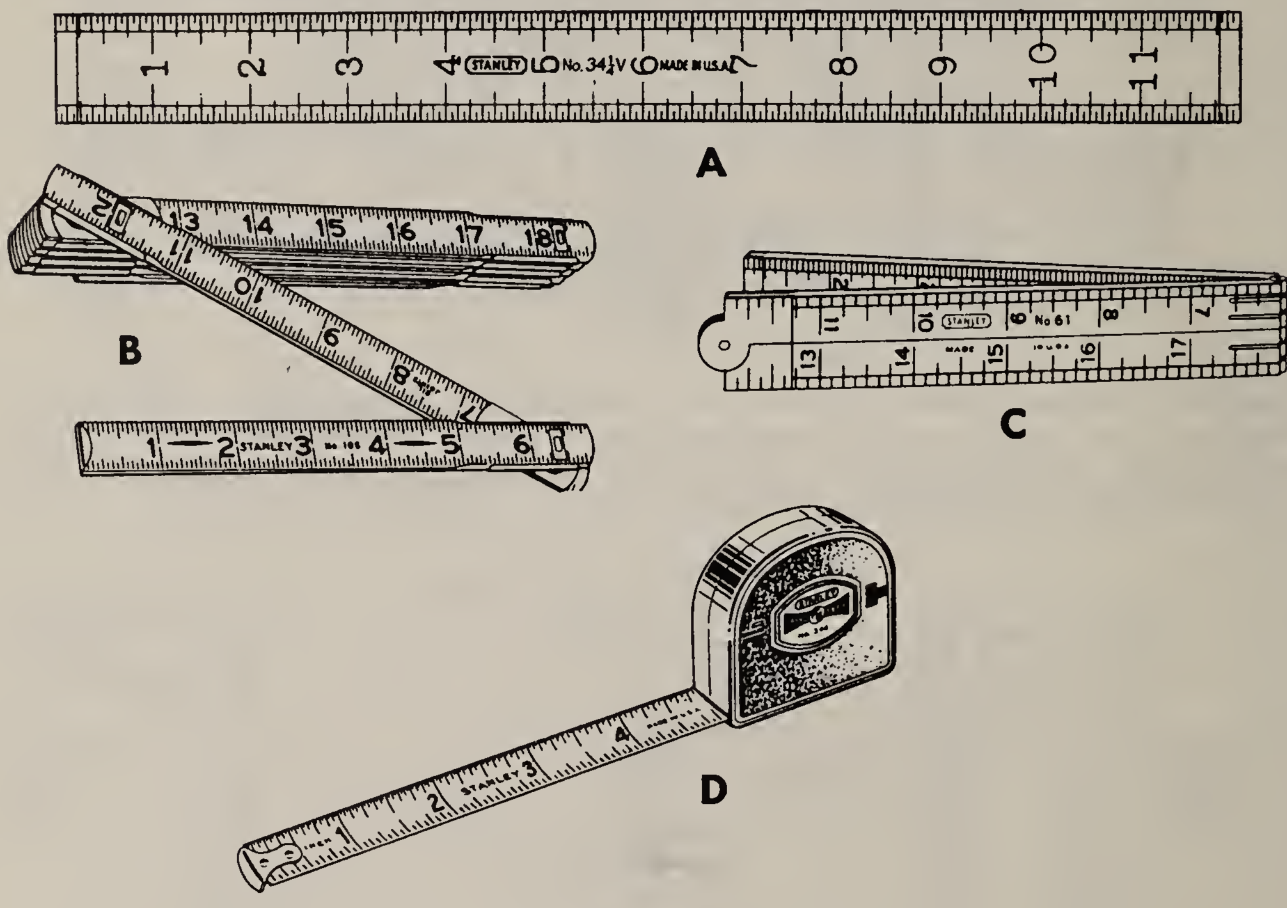


Fig. 12. Various types of measuring rules. In the figure, (A) represents a bench rule; (B), zigzag rule; (C), folding rule and (D), pull-push flexible steel rule. The foregoing rules are readily adaptable for various types of wood measurements. The bench rule is used for measuring and drawing straight lines up to two feet in length, the zigzag rule for measuring distances up to six feet or longer, the two-foot folding rule for measuring short distances and the pull-push rule for measuring short distances up to ten feet.

The Double-Bar Marking Gauge—A double-bar marking gauge is designed especially for mortise marking and has two independent bars working in the same head, as shown in Fig. 16. One pin is affixed to each bar. After setting the bars for the proper marking of the mortise, one side is marked with one bar of the gauge, then turned over for marking the other side. The setting can be retained for marking all mortises.

The Slide-Marking Gauge—An objection to the double-bar marking gauge is that two operations are required which can be

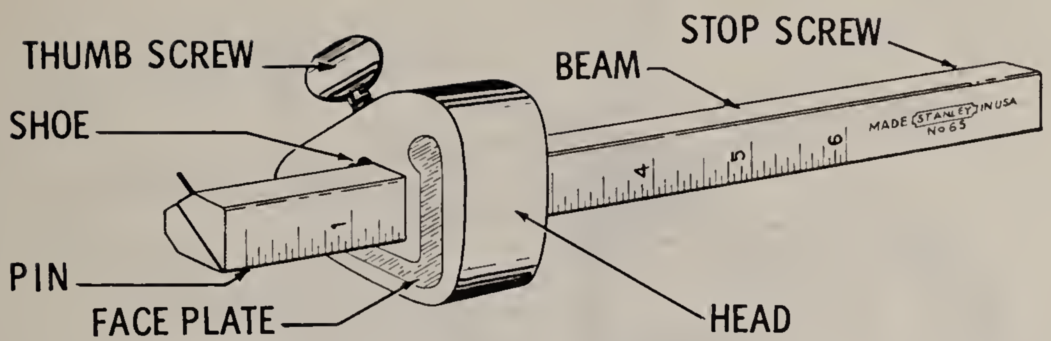


Fig. 13. Single-bar marking gauge. It is fitted with a head, faceplate, and thumbscrew and provided with a scale graduated in inches and sixteenths.

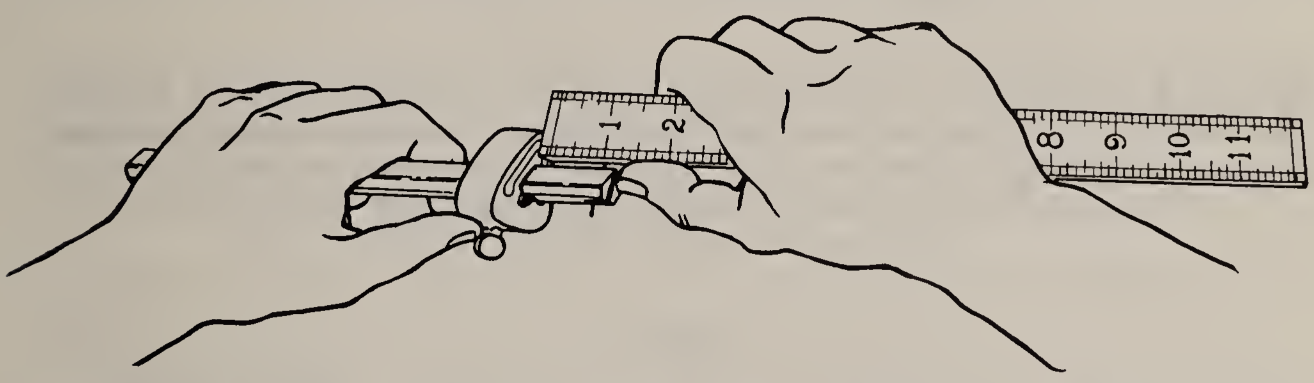


Fig. 14. How to set a marking gauge. Observe distance from head to pin. Check measurement after tightening of thumbscrew.

Fig. 15. Method of using a marking gauge. In setting the gauge, use a rule unless it is certain that the scriber point is located accurately with the graduations on the bar. In marking, the gauge should be held as indicated, the face of the head being pressed against the edge of the board, care being taken to keep it true with the edge so that the bar will be at right angles with the edge and the line scriber at the correct distance from the edge. The line is scribed usually by pushing the gauge away from the worker. Always work from the face side as shown.

performed in one operation with a slide-marking gauge. As shown in Fig. 17 the underside of the bar is provided with a flush side having a scriber (B) at the end of the slide, and another scriber (A) at the other end of the bar. These two scribers, when set to

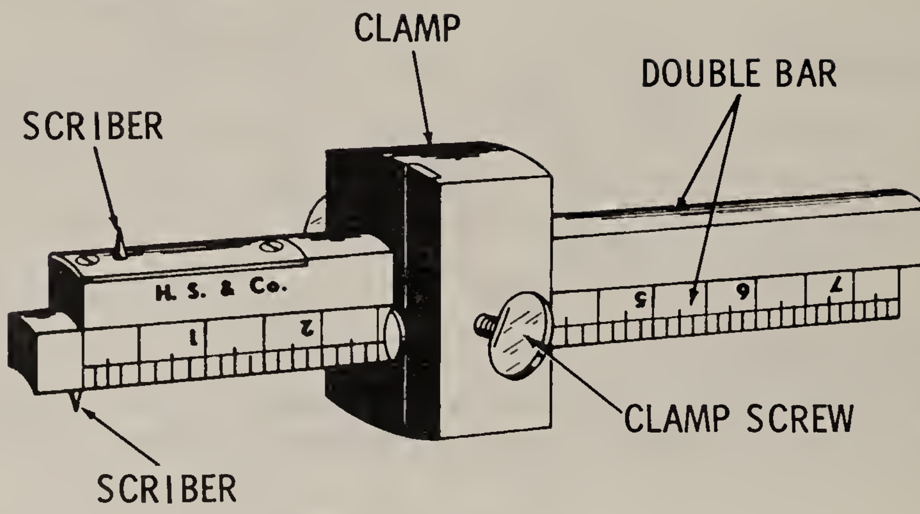


Fig. 16. Double-bar marking gauge. It is used for marking a given distance between two parallel lines and a given distance from the edge of a board. As noted in the illustration, each bar has a setscrew for clamping it in any desired position. This type of gauge is useful for making frames for panels, and other similar work.

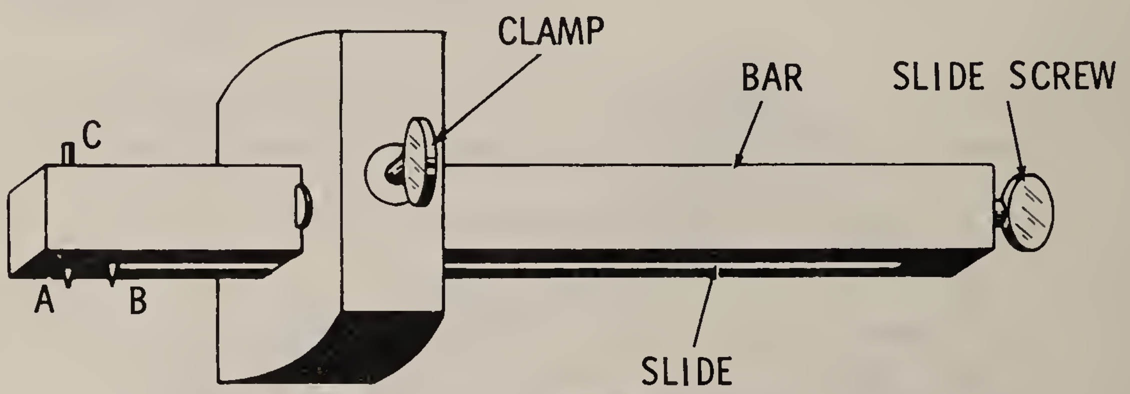


Fig. 17. Typical slide-marking gauge. In construction, the bar has a scriber (C), on the upper side for single marking, and a scriber (A), on the lower side which, with the scriber (B) on the slide, works flush in the bar as shown. A bar of this type is used for double marking. In certain work requiring two or more parallel lines, this marking gauge is preferred to any other since it is somewhat simpler in operation.

the required distance from the head, mark with one stroke both sides of the tenon or mortise to the size required. On the upper side is another scriber (C) for single marking.

Butt Gauges—These are used almost exclusively for hanging of doors where there are three measurements to be marked, namely the location of the butt on the casing, the location of the butt on the door and the thickness of butt on both casing and door.

Butt gauges have three separate cutters arranged with the necessary clearances so that no change of setting is needed when hanging a number of doors. Thus, in reality, a butt gauge comprises a rabbet gauge, marking gauge, and mortise gauge all in one and of

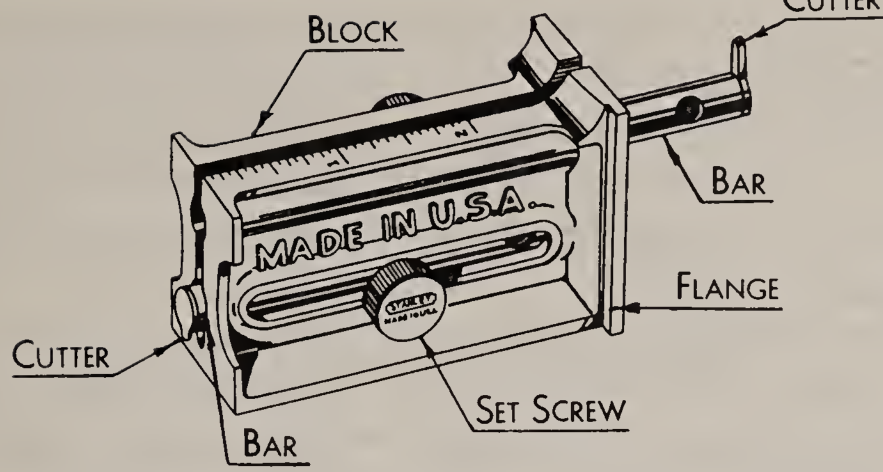


Fig. 18. The butt gauge. It is used to mark location of butt on casing and on door. Three separate cutters, one for each dimension, eliminate change of setting when more than one door is hung. Also used as a marking and mortising gauge and inside and outside square for squaring edge of butt on door and jamb. It is graduated in 16ths for two inches.

a scope sufficient for all door trim, including lock plates, strike plates, etc.

Drill Gauges—These are used for drill-size determination, but are also useful in measuring the size of tubular objects such as rods and wires. As noted in Fig. 19, to use a gauge of this sort, the twist drill is inserted into the smallest possible hole of the gauge, and since each hole is labeled with both the number of the drill and its decimal equivalent, the diameter of the drill to be tested for size is thus determined.

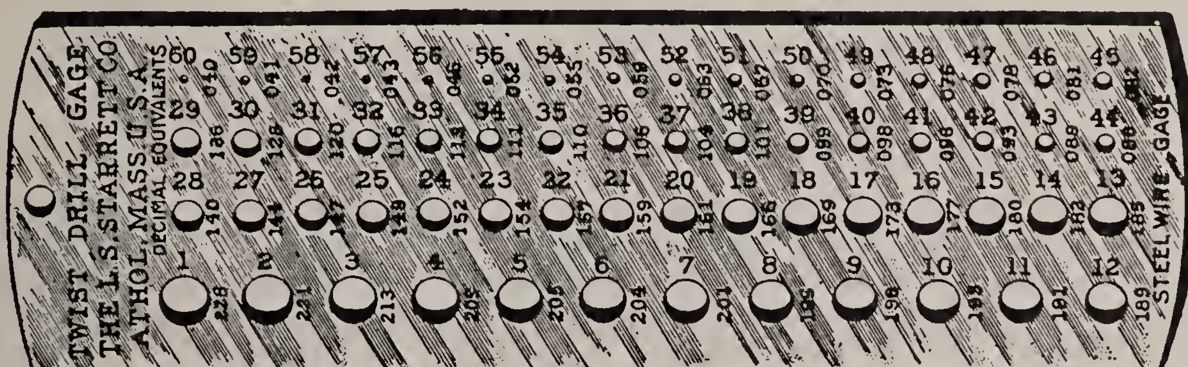


Fig. 19. Typical drill gauge. This gauge gives the number of the drill to fit each hole, and the size of the hole in thousands of an inch. It is hardened, ground, and rubbed to a bright finish and thoroughly tested after hardening.

Many drill gauges also contain other useful information and reference materials, such as wire size and correct size of drills to use for tap holes.

Sheet-Metal Gauges—A sheet-metal gauge as shown in Fig. 20 consists essentially of a slotted circular disk. These slots are

numbered in thousandths of an inch on one side of the disk and in gauge size on the other. To find the thickness of the metal part to be measured, insert the edge of the metal in the smallest possible slot of the disk and read the gauge number and thickness in thousandths of an inch directly opposite the slot used in the measurement.

Sheet-metal and wire gauges are made in a great variety of sizes and standards, such as the American Gauge or Brown & Sharpe Wire Gauge, the English or Birmingham Standard, the Imperial Standard, etc.

Fig. 20. Typical standard gauge for sheet and plate iron and steel. The gauge numbers shown are United States Standard, the recognized commercial standard in the United States for uncoated sheet and plate iron and steel and is based on weights in ounces per square foot. The gauge shown is carefully tested after hardening and has decimal equivalents of each number stamped on the reverse side.

GUIDING AND TESTING TOOLS

The success of any woodworking project depends upon accuracy in measurement and in fitting parts together at the correct angle. To insure accuracy, various tools of guidance and direction are used; otherwise, joints, etc., could not be made with precision. The proper use of accurate tools is essential to precision.

Straightedge—This tool is used to guide the pencil or scriber in marking a straight line, and in testing a faced surface such as the edge of a board to determine whether it is straight. Any object having an edge known to be straight, as the edge of a steel gauge, may be used for this purpose; however, a regular straightedge is preferable. A straightedge may be made of either wood or metal, and in any length from a few inches to several feet. When great

Fig. 21. Typical steel straightedges. These tools are used where straight lines are to be scribed or where surfaces must be tested for flatness. Depending on their use, straightedges are manufactured in lengths of from 12 to 72 inches, widths of 1⅜ to 2½ inches, and thicknesses of 1/16 to ½ inch.

accuracy is required, wood is objectionable because of its tendency to warp or spring out of shape.

The Square—Although the square was designed originally for measuring angles, it is a convenient tool for measurement of length

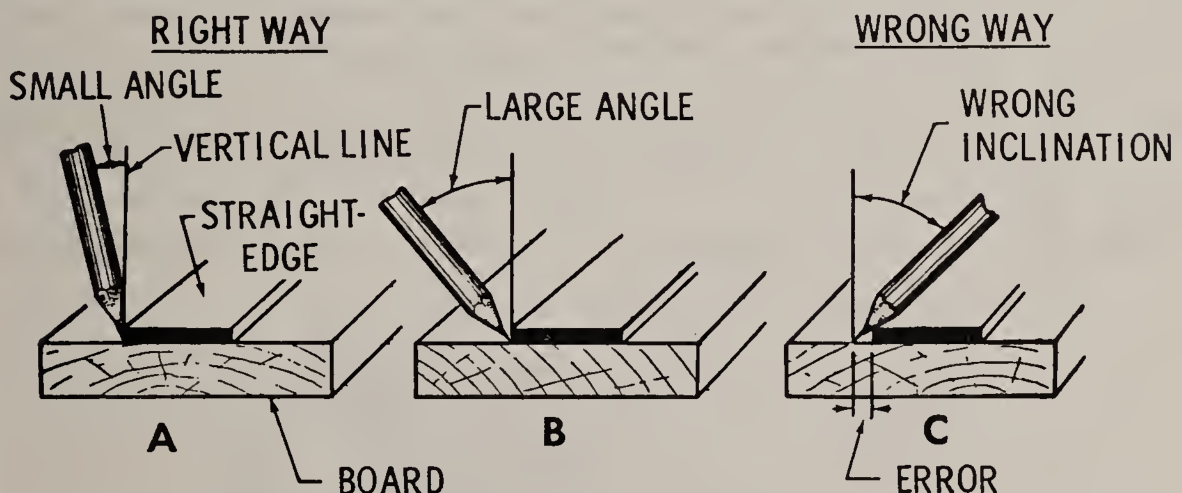


Fig. 22. Right and wrong inclinations of the pencil in marking with the straightedge. (A) the pencil should not be inclined from the vertical more than is necessary to bring the pencil lead in contact with the guiding surface of the straightedge. (B) when the pencil is inclined more, and pressed firmly, considerable pressure is brought against the straightedge, tending to push it out of position. (C) if the inclination is in the opposite direction, the lead recedes from the guiding surface, introducing an error which is magnified when a wooden straightedge is used because of the greater thickness of the straightedge.

as well. There are several types of squares used in woodworking, such as:

1. Try square
2. Try and miter square
3. Steel square

4. Combination square
5. Framing square

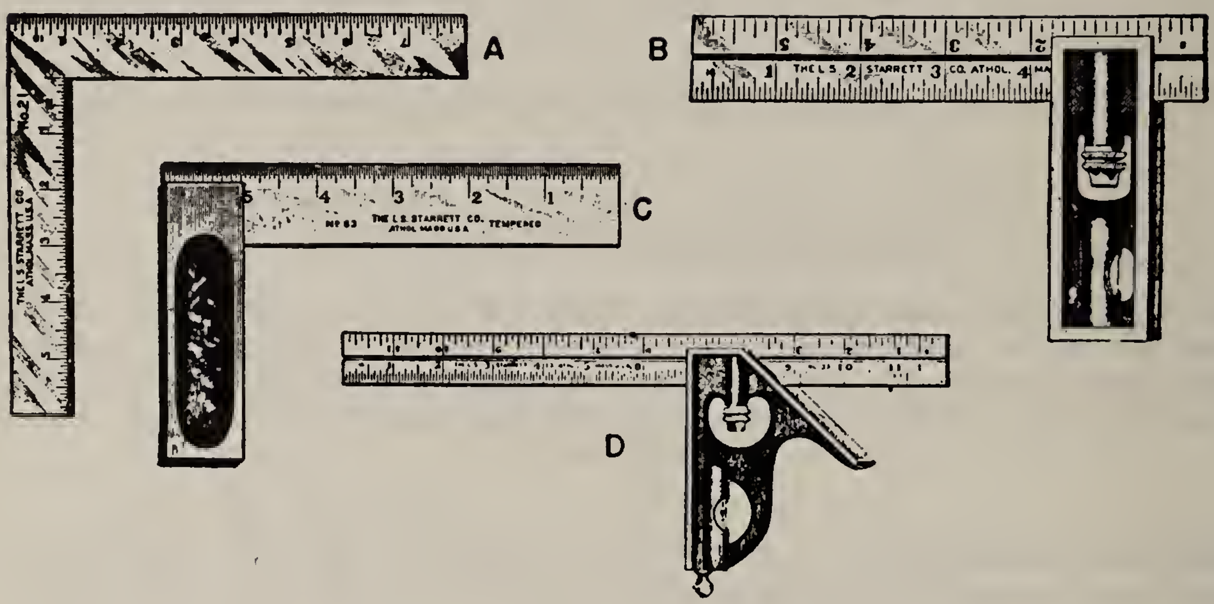


Fig. 23. Various types of squares. In the figure, (A) represents a steel square; (B) a double try square; (C(a try square; (D) a combination square. This last square consists of a graduated steel rule with an accurately machined head. The two edges of the head provide for measurements of 45 degrees and 90 degrees respectively.

Try Square—The ordinary try square used by woodworkers consists of a steel blade set at right angles to the inside face of the handle in which it is held. The stock is made of hardwood

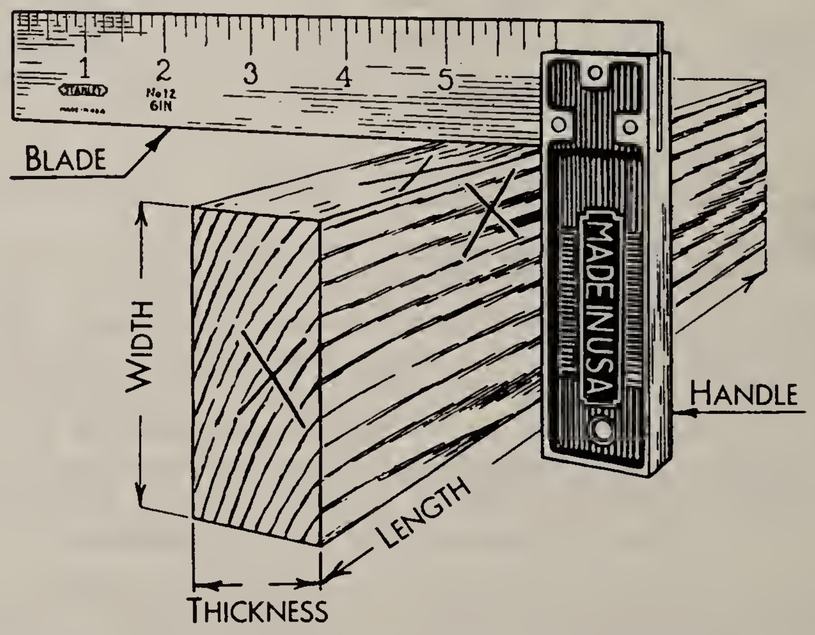


Fig. 24. Use of the try square to square stock. When testing ends, edges or scribing lines, hold the handle of the try square against the stock. The square should be placed in several positions along the edge. If light shows under the blade, it indicates that the surface is not at a 90° angle with the side of the stock or "square" at that section, and all such places must be trued.

and is usually faced with brass in order to preserve the wood from damage, or it may be made entirely of steel.

The usual sizes of try squares have blades ranging from about 3 inches to 15 inches in length. The handle is thicker than the blade, which is inserted midway between the sides of the stock. The handle is made thicker than the blade so that its face may be applied to the edge of the wood and the steel blade laid on the surface to be marked. The blade is usually provided with a scale of inches divided into eighths.

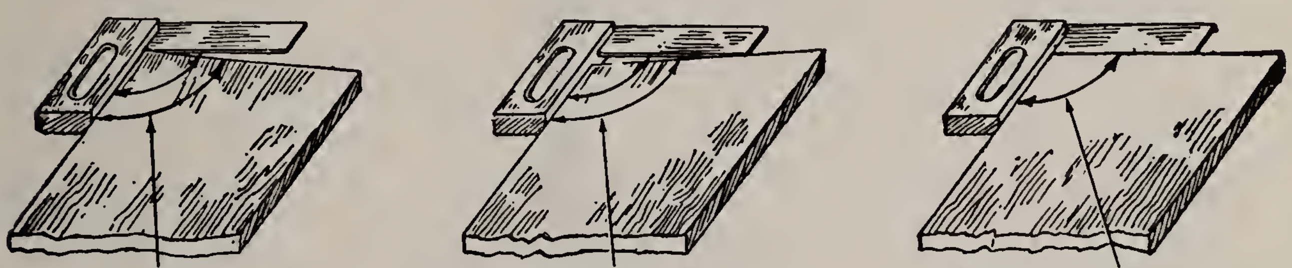


Fig. 25. Applications of the try square for testing the end of a board to determine if the end is "square" with the longitudinal edge of board. (A) and (B) show ends at angles smaller and greater than 90° angle, and (C) shows an end at 90° angle or "square."

Try and Miter Square—The term miter, strictly speaking, signifies any angle except a right angle, but as applied to miter squares means an angle of 45°. The blade of the miter square is permanently set at an angle of 90° with the stock but one edge of the stock is at 45° with the blade. The method of testing is shown in Fig. 27, and this test should be made not only at the time of purchase, but frequently afterwards, as the tool may become inaccurate from dropping or rough handling.

Framing Square—A framing square has a framing table and various other scales especially adapted for use in house framing, although its range of usefulness makes it a valuable tool for any woodworker. Fig. 28 shows the general appearance and application of a steel square for various types of measurements.

Combination Square—This tool can be used for the same purpose as the ordinary try square, but it differs from the try square in that the head can be moved along the blade and clamped at any desired place. A level and miter are combined with the square.

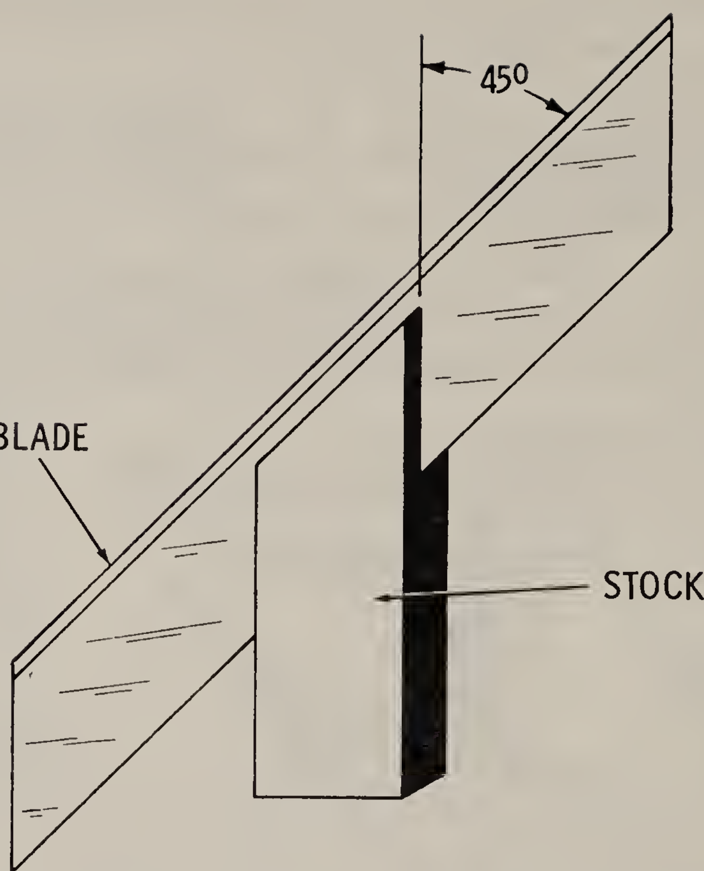


Fig. 26. *Typical miter square. It differs from the ordinary try square in that the blade is set at an angle of 45° with the stock and the latter is attached to the blade midway between its ends.*

The sliding head contains a guide which travels in a central groove in the blade. This design permits the scale to be pulled out and used as a rule.

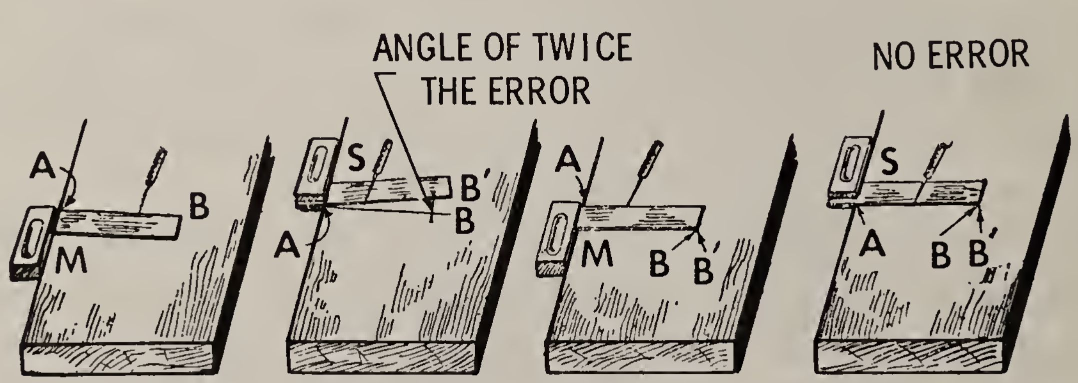


Fig. 27. *Method of testing a try square. If the square is "out" (angle not 90°), scribed lines AB and AB' for position M and S of the square (left-hand side) will not coincide. Angle BAB' is twice the angle of error. If the square is correct, lines AB and AB' for positions M and S will coincide (right-hand side).*

The construction of this square also makes it convenient to square a piece with a surface and at the same time tell whether

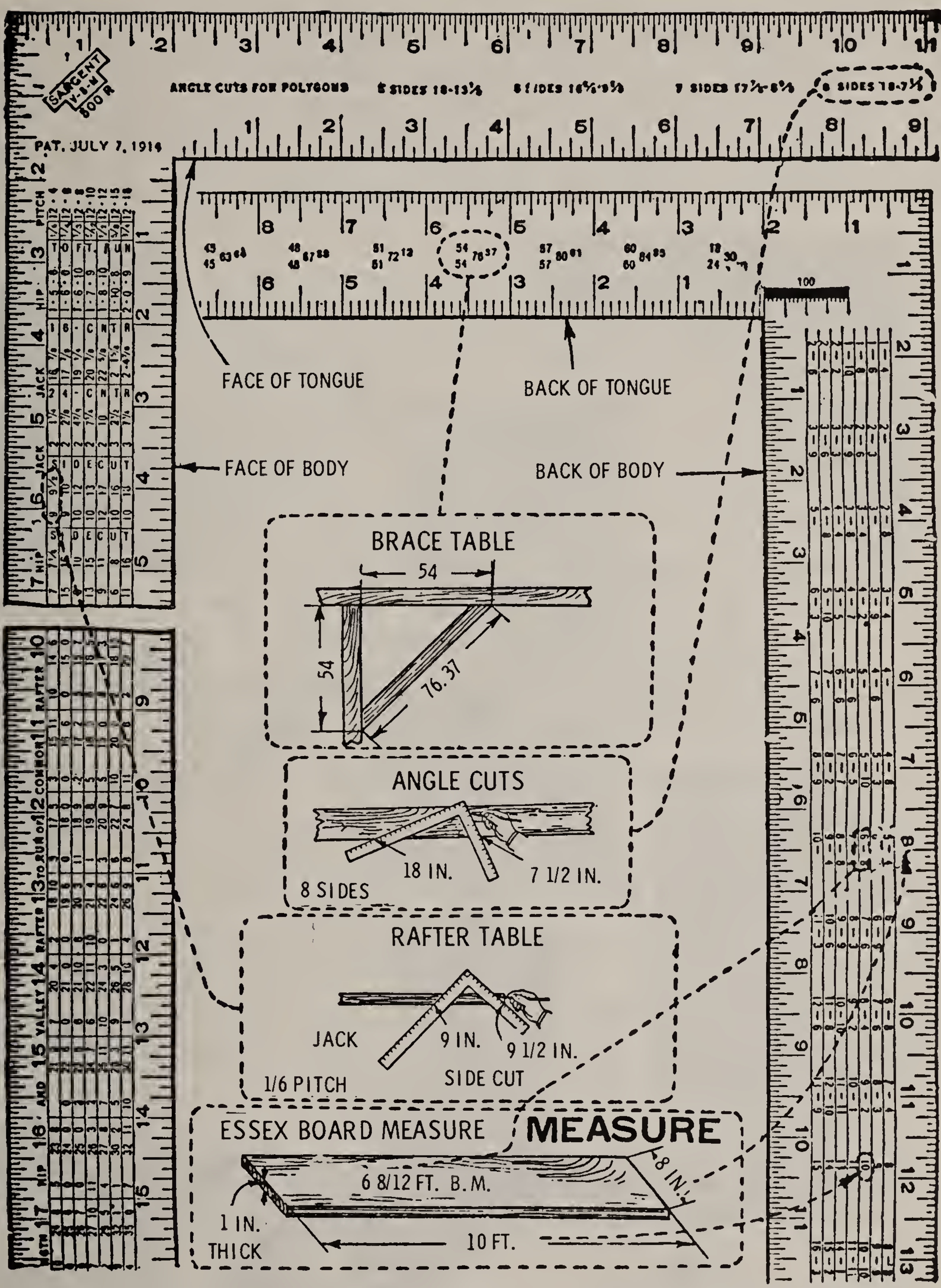


Fig. 28. Front and back views of a typical framing square.

one or the other is level or plumb. The spirit level in the head of the square permits this to be done without the use of a separate level. The head of the square may also be used as a simple level.

Because the scale may be moved in the head, the combination square makes a good marking gauge. The head can be moved along

the scale to the proper position and clamped there. The combination square may then be moved along the work as with any ordinary gauge. As a further convenience, a scriber is held in the head by a small brass bushing. The scriber head projects from the bottom of the square stock in a convenient place to be taken out quickly.

In layout work, the combination square may be used to scribe lines at miter angles as well as at right angles, for one edge of the square head is at 45°. Where micrometer accuracy is not essential, the blade of the combination square may be set at any desired length within its range and the square used as a depth gauge to measure in mortises, or the end of the scale may be set flush with the edge of the square and used as a height gauge.

The head may be unclamped and entirely removed from the scale and a center head substituted, so that the same tool can quickly be used to find the centers of shafting or other cylindrical pieces. In the best construction, the blade is hardened to prevent the corners from wearing round and the graduations from being destroyed, thus keeping the scale accurate and easy to read at all times.

The combination square, combining as it does a rule, square, miter, depth gauge, height gauge, level and center head, permits more rapid work on the part of the woodworker or mechanic, saves littering the workbench with a number of tools, some of which may be used only rarely, and tends toward greater efficiency. Fig. 29 shows a combination square and center-head attachment, and Fig. 30 shows some of the uses for the tool.

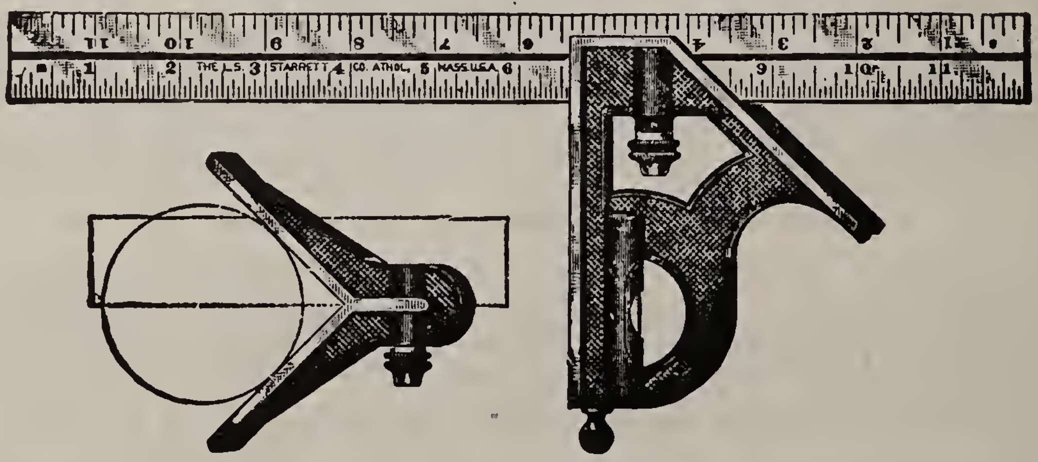


Fig. 29. Typical combination square with grooved blade, level and centering attachments.

The Sliding "T" Bevel—A sliding "T" bevel is similar to a try square but has a sliding adjustable blade that can be set at any angle with the stock. In construction, the stock may be of wood or steel. When of wood, it has brass mountings at each end and is sometimes concave along its length. The blade is of steel with

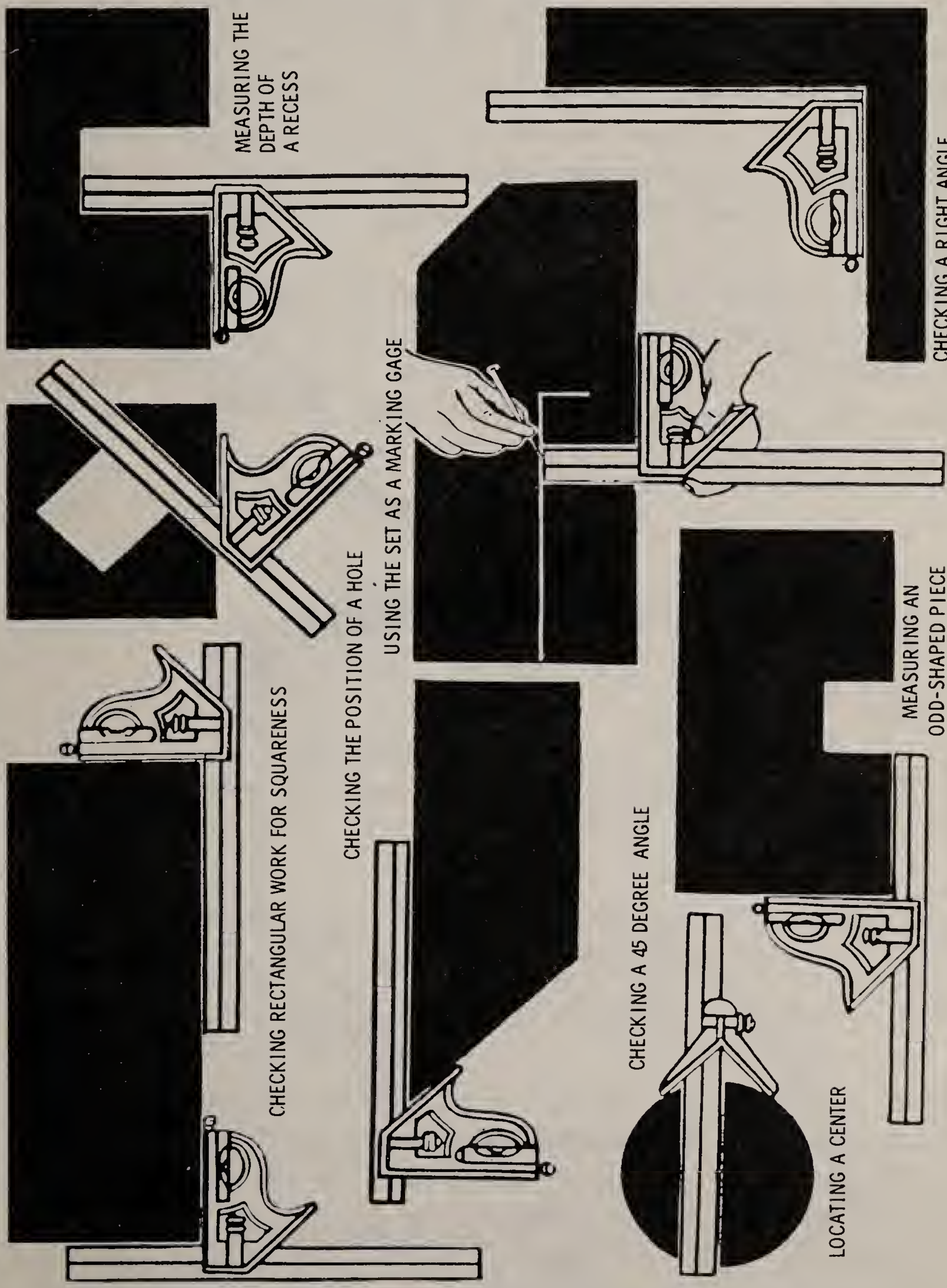


Fig. 30. Some of the many uses of the combination square.

parallel sides and its end is at 45° with the sides, as shown in Fig. 31 .The blade is slotted, allowing linear adjustment, and a pivot or screw pin is located at the end of the stock.

When the blade has been adjusted to a particular angle, it is secured in position by tightening a clamping screw located either on the pivot or, as shown in Fig. 31, at the end of the stock. In selecting a sliding "T" bevel, care should be taken to see that the edges are parallel and that the pivot screw, when tightened, holds the blade firmly without bending it. In the line of special bevels there are various modifications of the standard or ordinary form of bevel just described. Uses for the sliding "T" bevel are shown in Fig. 33.

Angle Divider—This is another tool for bisecting or dividing angles, and is especially useful for fitting trim, moldings, flooring, etc., into corners. It may also be used as a try square. The tool is graduated on one side for laying out four-, five-, eight- and ten-

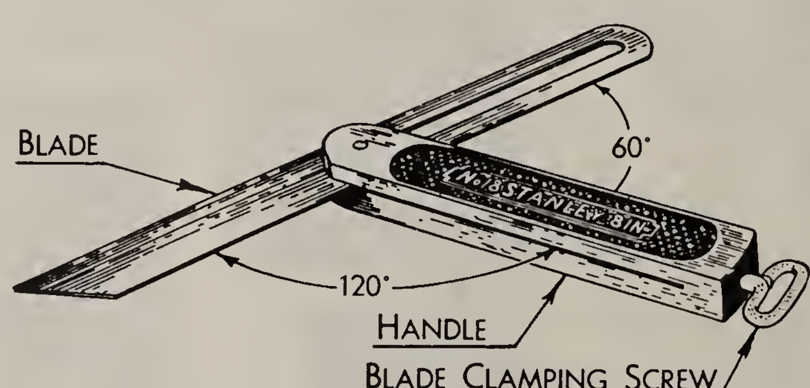


Fig. 31. Sliding "T" bevel. A tool of this type is used in marking and testing angles.

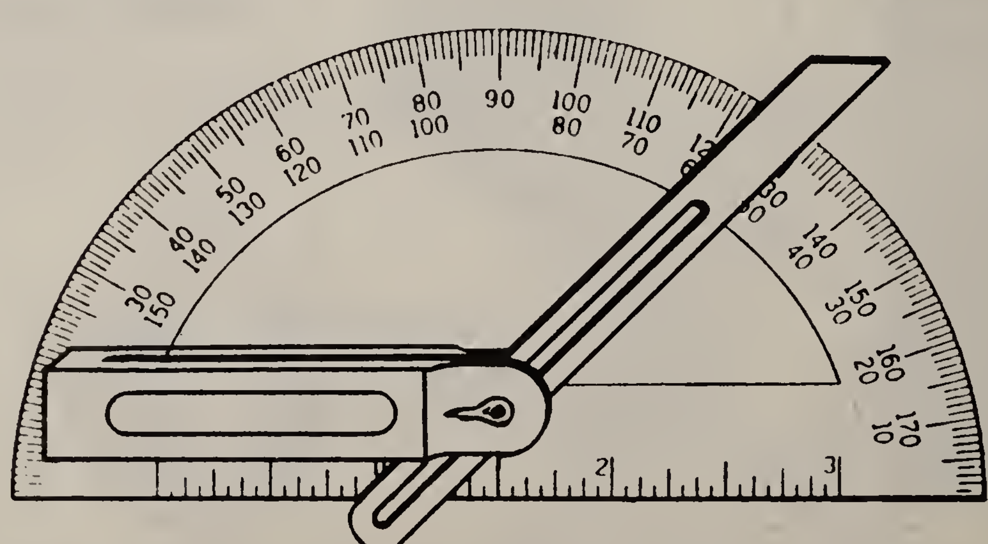


Fig. 32. Method of setting the sliding "T" bevel with the protractor.

sided work. Steel arms can be locked at any desired angle. The corner angle is first measured accurately by adjusting the angle divider to fit the corner. As noted in Fig. 36, the center shaft is always the center line for the two arms; thus, by laying the center shaft along the molding or other work, the correct bisected angle is marked. By reversing the angle divider, the corresponding angle can be marked on the opposite piece.

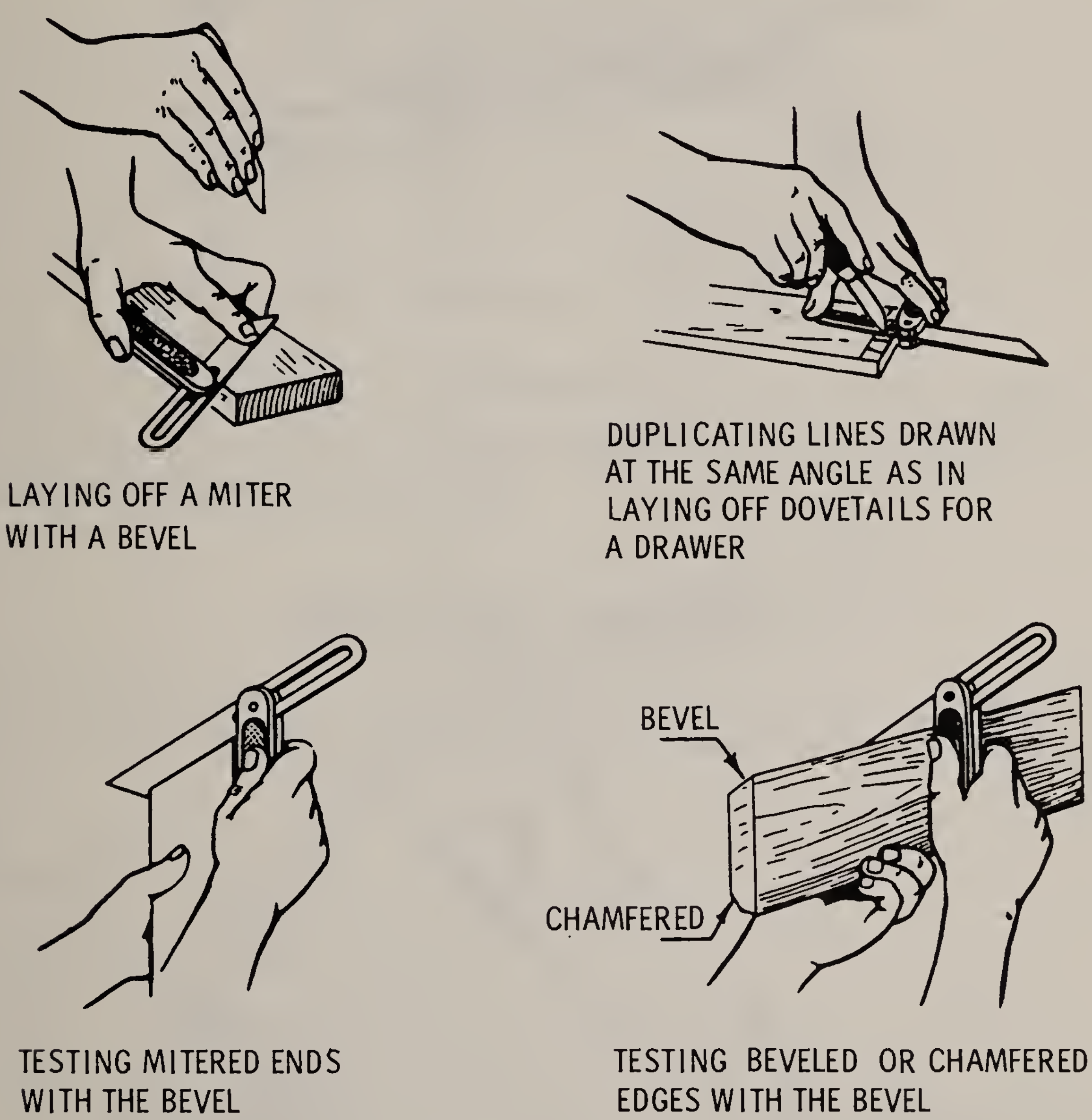


Fig. 33. Some of the uses for the sliding "T" bevel.

The Miter Box—This is a device used to guide the saw in cutting work to form miters and consists of a trough formed by the bottom and its two side pieces of wood screwed together as illustrated in Fig. 37. As noted in the illustration (Fig. 38), the miter box may be designed for cutting at any angle. A homemade miter box can be constructed easily and quickly.

The Level—This tool is used for both guiding and testing, to guide in bringing the work to a true horizontal or vertical position, and to test the accuracy of the completed work or construction. It consists principally of a long rectangular piece of wood or metal, cut away on its side and near the end to receive two glass tubes which are almost entirely filled with a nonfreezing liquid

POLYGONS AND THEIR MITERS

USE FIGURES ON SQUARE

	Tongue	Blade		Tongue	Blade
3 Sides	12 in.	20⅞ in.	10 Sides	12 in.	3⅞ in.
4 "	12 "	12	11 "	12 "	3 17/32 "
5 "	12 "	8 25/32 "	12 "	12 "	3 7/32 "
6 "	12 "	6 15/16 "	14 "	12 "	2¾ '
7 "	12 "	5 25/32 "	16 "	12 "	2 13/32 "
8 "	12 "	4 31/32 "	18 "	12 "	2⅛ "
9 "	12 "	4⅜ "	20 "	12	1 29/32 "

As Shown Below

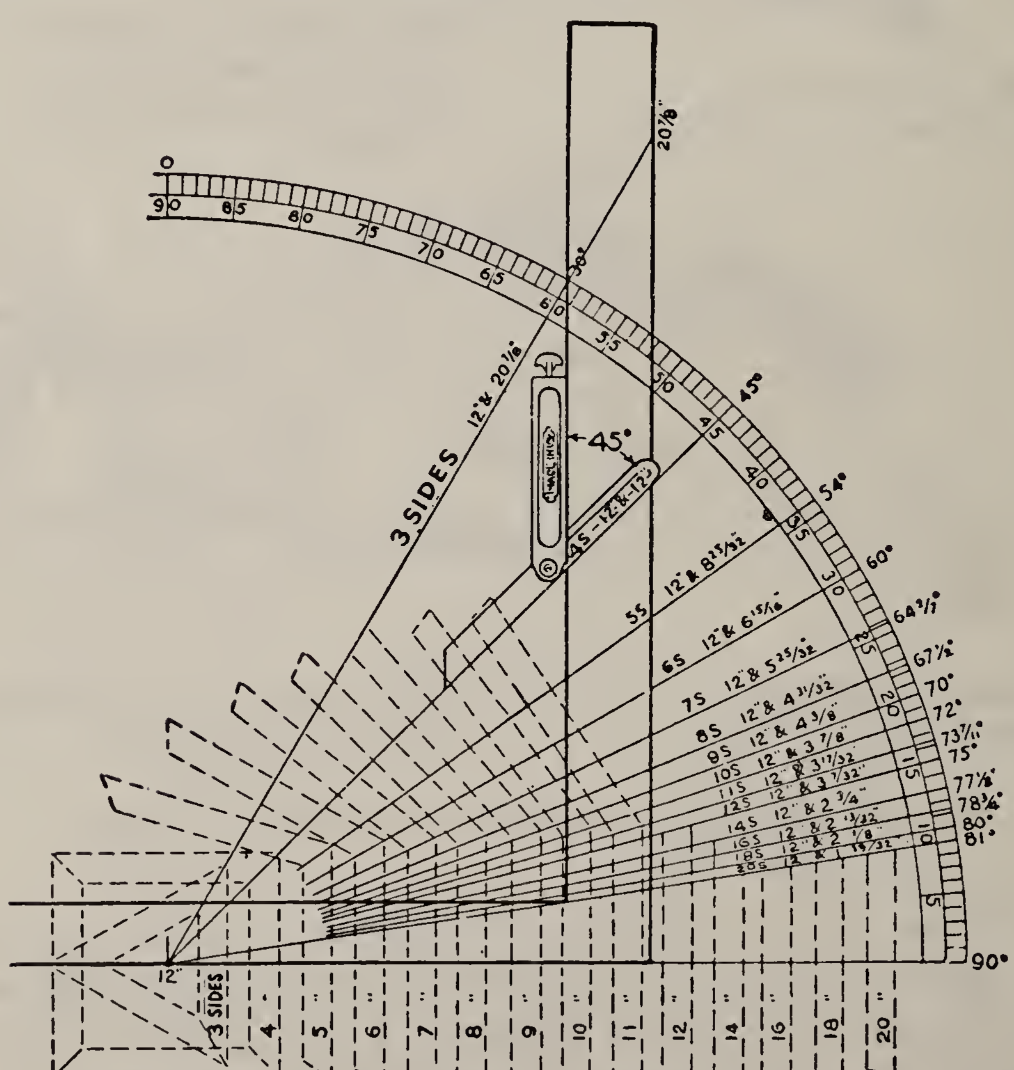


Fig. 34. Polygons and their miters determined by the use of framing square. Set the bevel for these angles with the steel square to obtain any angle required for the construction of various polygons as noted in the accompanying table.

having a small bubble free to move as the level is moved. A satisfactory level is an essential for any workshop.

The side and end tubes are at right angles, so that when the bubble of the side tube is at center of the tube, the level is horizontal. When the bubble in the end tube is at the center, the level

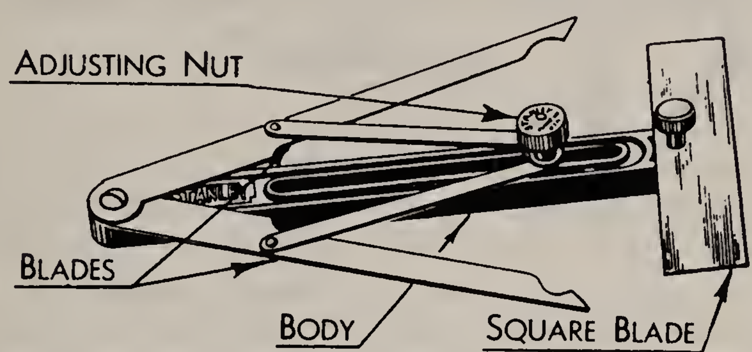


Fig. 35. Double-bevel angle divider.

is vertical. Accordingly, by holding the level on a surface supposed to be horizontal or vertical, its true position may be ascertained by noting the position of the bubble.

HOLDING TOOLS

An essential part of the equipment necessary in a woodworking shop is a proper assortment of holding tools, because there are

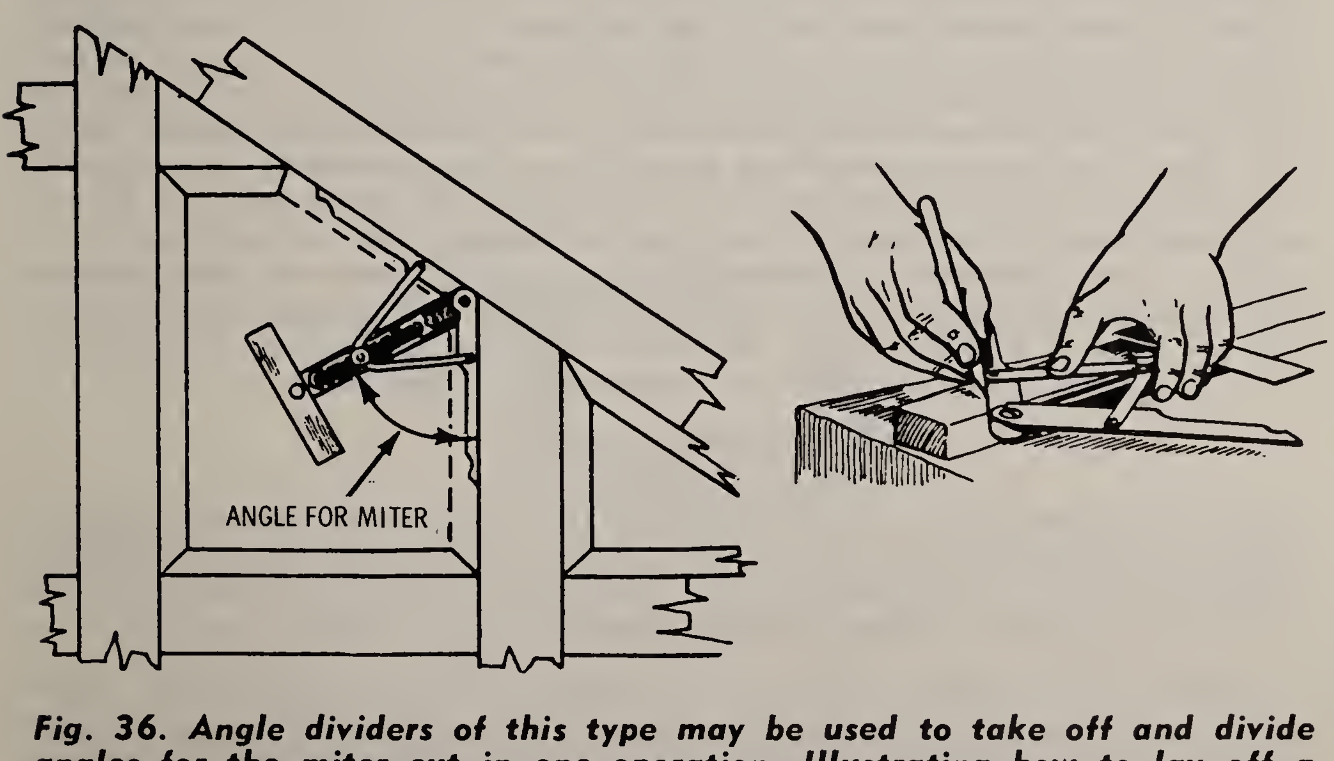


Fig. 36. Angle dividers of this type may be used to take off and divide angles for the miter cut in one operation. Illustrating how to lay off a miter. The square blade on the angle divider may be used as a try square.

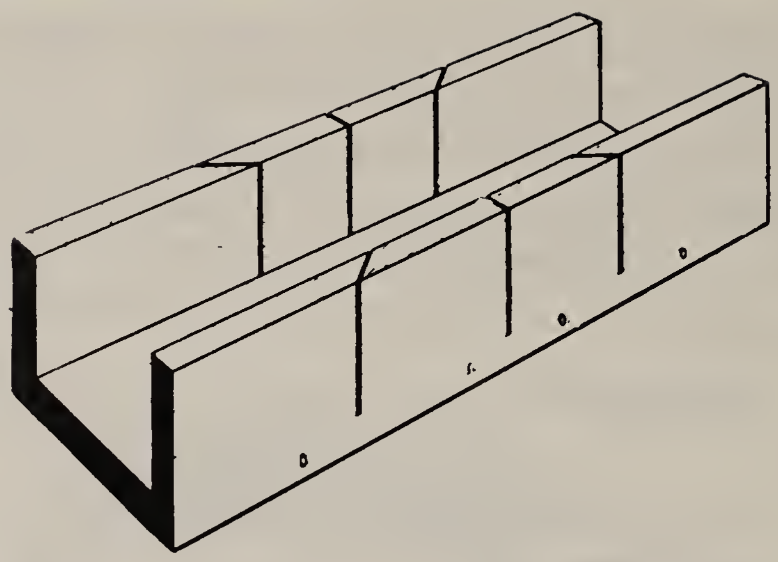


Fig. 37. Typical wooden miter box. A nonadjustable 45- and 90-degree miter box of the type shown may easily be constructed from three suitable pieces of hardwood screwed together as indicated.

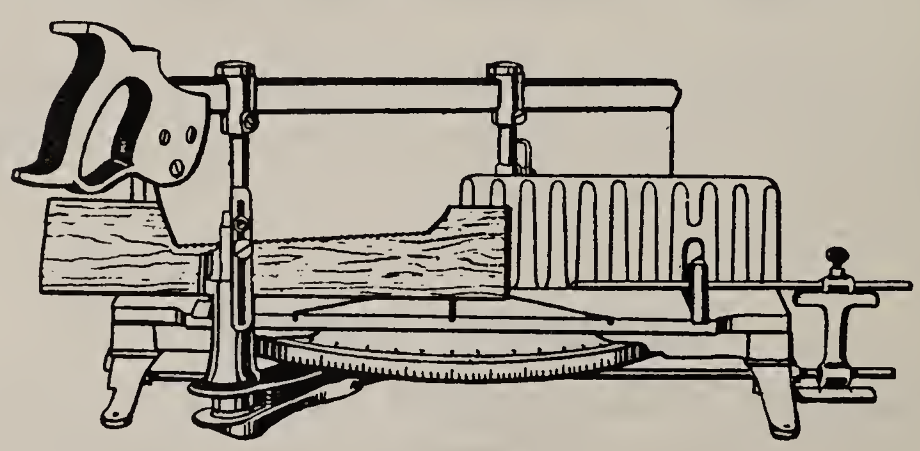


Fig. 38. Miter box. The saw-guide uprights are securely clamped in tapered sockets in the swivel arm and can be adjusted to hold the saw without play and also to counteract a saw that does not run true because of improper setting or filing. The second socket in the swivel arm permits the use of a short back saw or allows much longer strokes with the standard miter saw. The swivel arm can be set by a pin stop at the commonly used angles. The edge of the base is graduated in degrees and the swivel arm can be set and automatically fastened at any degree desired. The uprights at front and back are graduated in sixteenths of an inch, and movable stops can be set by means of thumbscrews to the depth of the cut desired. Stock guides hold all types of ordinary work, as well as irregular forms, and can be used as length gauges for duplicating short pieces.

numerous operations which require that the work be held rigid, even when considerable force is applied, as in planing and chiseling.

The workbench, considered broadly with its attachments, may be called the main holding tool, and unless this important part of the equipment is substantial and rigid, it will be difficult to turn out good work. Holding tools may be classified broadly as:

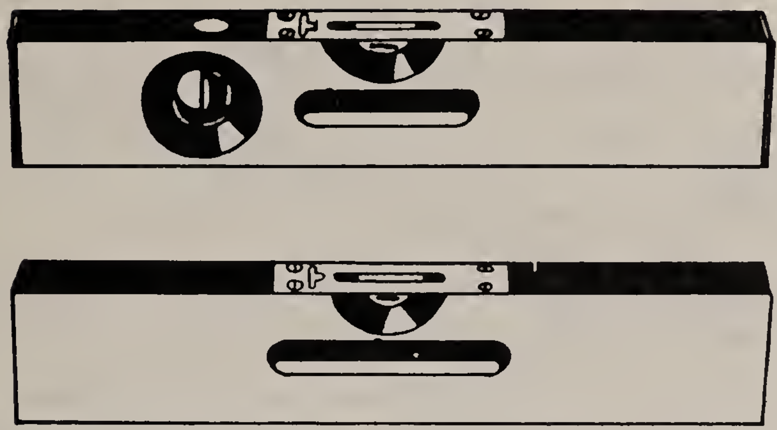


Fig. 39. Typical inexpensive wood levels used in woodworking shops. As shown, levels of this type may, in addition to the horizontal or level glass, also have a plumb glass to ascertain the true vertical position of work or object.

1. Supporting
2. Retaining

In woodworking shops having ample space, a couple of sawhorses or "trestles" may be used to good advantage when the material is of such dimensions that the workbench cannot conveniently be used for marking and sawing boards.

Clamps—In most woodworking operations it is necessary frequently to press pieces of wood tightly together, particularly those that have been mortised-and-tenoned, tongued-and-grooved, or simply glued. The bench vise is not always a convenient tool for this purpose, or its use may be required for other work. In such cases, clamps are used. A great variety of clamps for various

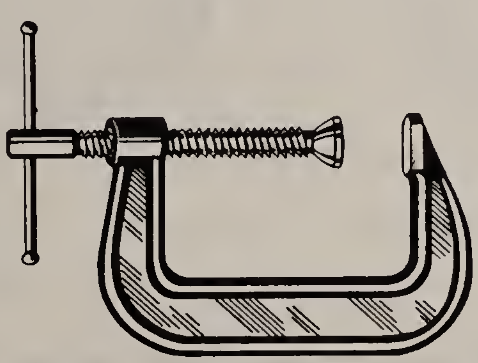


Fig. 40. Single-screw, iron-jaw clamp with swivel head on screw. Clamps of this type, often termed "C-clamps," are customarily used for clamping small pieces of wood and are made in openings which vary widely in size.

applications are available. Clamps may be divided into various types as:

1. Single-screw jaw or "C" clamp
2. Double-screw clamp or hand screw
3. Bar or pipe clamp
4. Miter clamp

The single-screw type includes the iron-jaw clamps of small and moderate opening as shown in Fig. 40. A form of double-screw clamp commonly called a "hand screw" is shown in Fig. 41. An advantage of this type of clamp is that the jaws cover a large area and can be adjusted exactly parallel to each other.

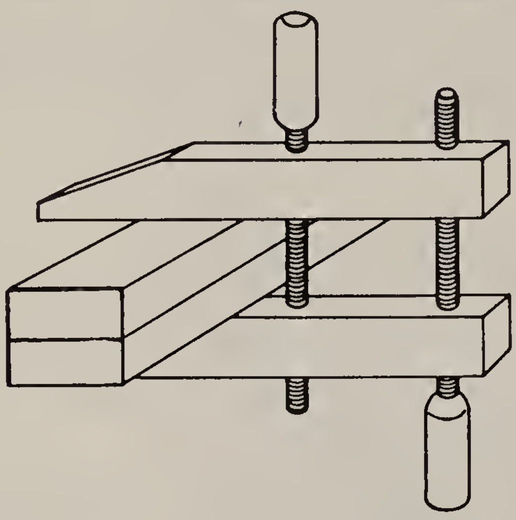


Fig. 41. Typical hand screws for clamping boards and blocks together after gluing.

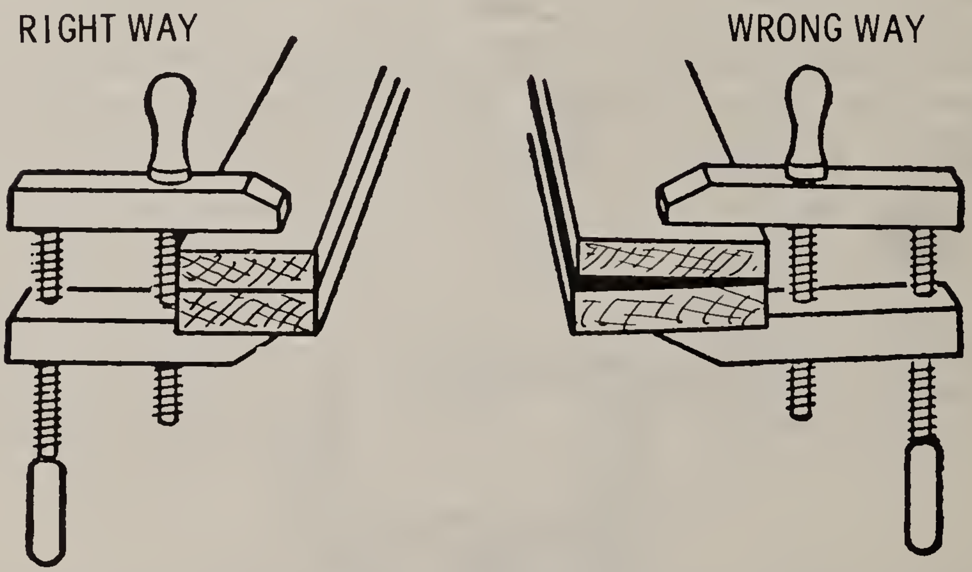


Fig. 42. Right and wrong ways to use hand screws. First set the jaws to approximately the size of the material to be clamped. In placing the hand screws upon the work, keep the points of the jaws slightly more open than the outer ends. Final adjustment of the inside screw will then bring the jaws exactly parallel, which is the proper position for clamping parallel work. Of course, if the work itself is wedge-shaped the clamp jaws should conform so that equal pressure is applied at all points of contact. Because the screws are made of wood instead of iron, proper judgment must be used with respect to the applied pressure.

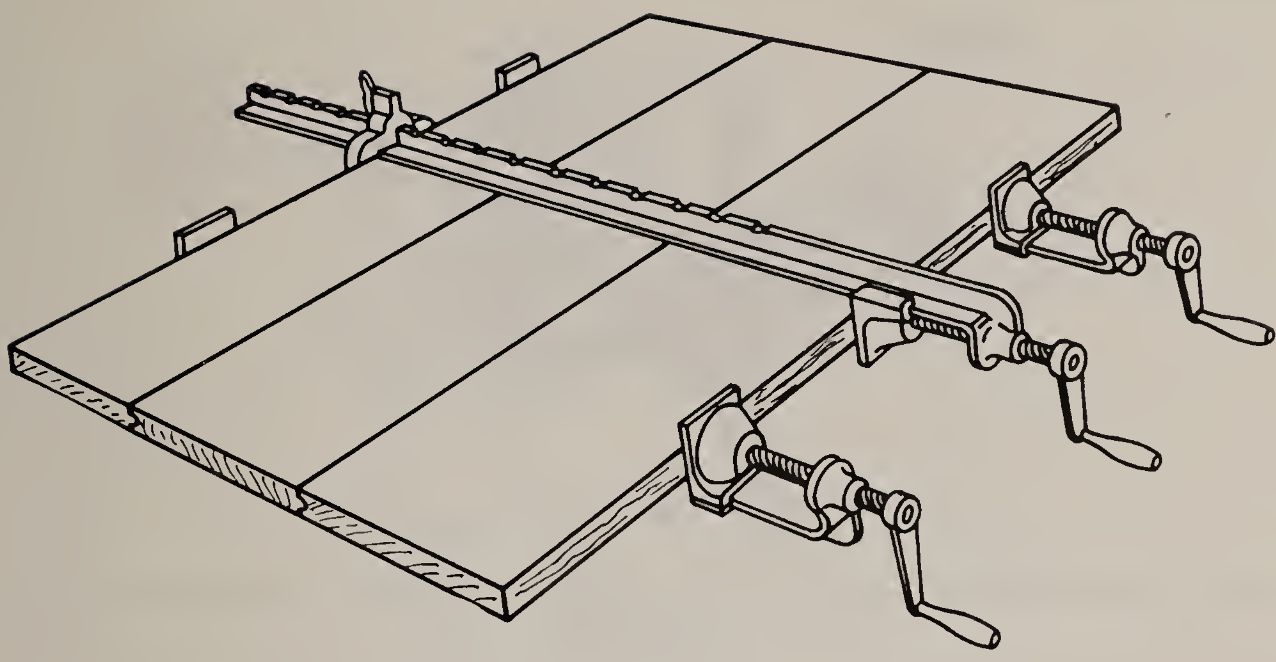


Fig. 43. Typical bar clamps and method of clamping. It is customary when clamping, to insert small blocks of wood underneath the swivel head and the sliding jaw to prevent the clamp from marring the work. This is true of any clamp where the jaws press material on which visible marks can be made.

Hand screws may be quickly opened or closed by grasping the screw handles, one in each hand, and revolving the clamp counter-clockwise or clockwise respectively (as viewed from the right hand). For large work, bar or pipe clamps are used. Attached to one end of the bar or pipe is a head in which the screw works. A jaw arranged to slide on the bar or pipe is quickly adjusted and secured in position.

Vises—These are manufactured in various sizes, the essential features being rigidity, weight and strength with accurately fitting and smoothly working parts. Rigidity and weight are required to make effective the effort expended on the work held in the vise. The "anvil quality" or inertia sufficient to effectively hold a piece of work solidly against a blow is a most important qualification in a vise, and a suitable mass of iron is just as necessary to supply

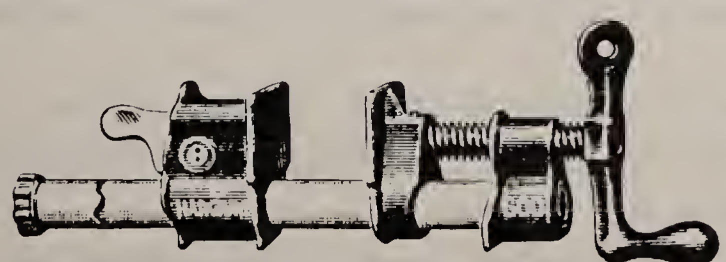


Fig. 44. Typical pipe clamps used in same manner as bar clamps.

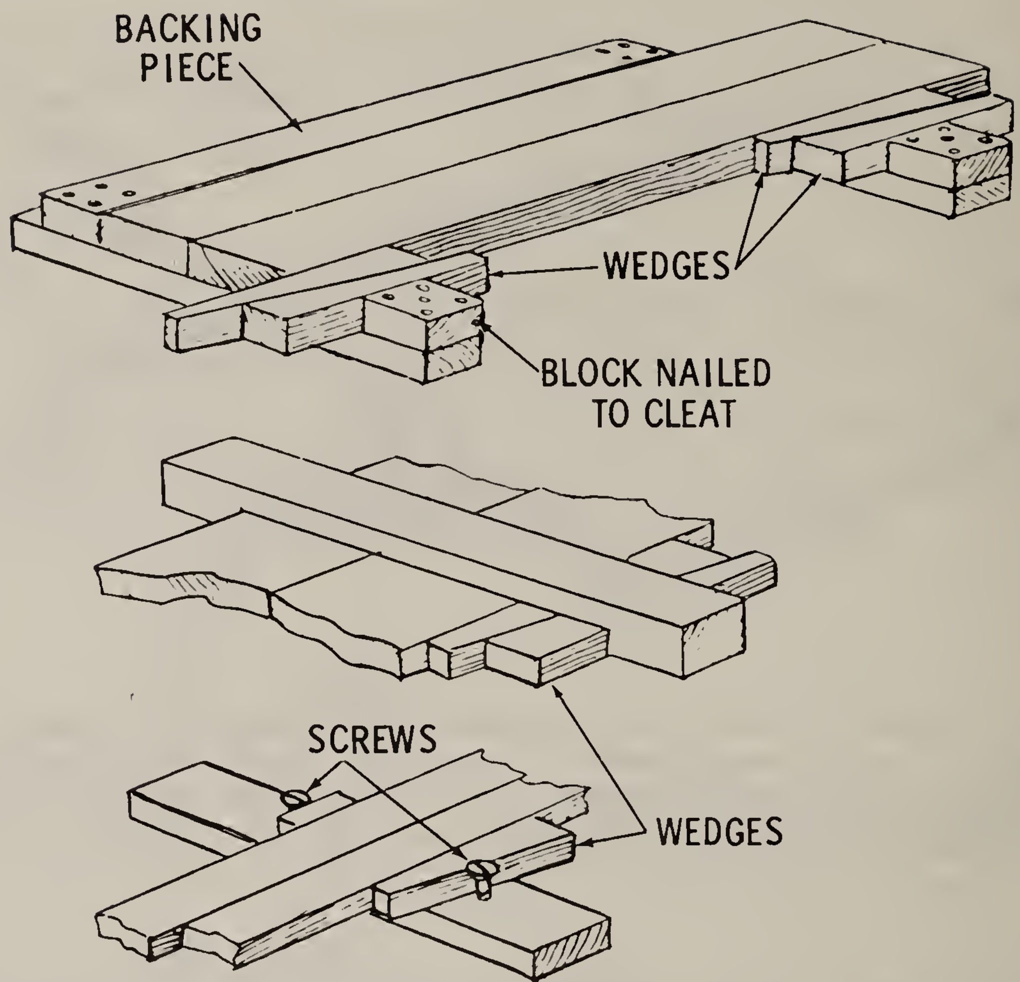


***Fig. 45.** Typical improvised clamping devices which may easily be constructed and used in the absence of hand screws or bar clamps.*

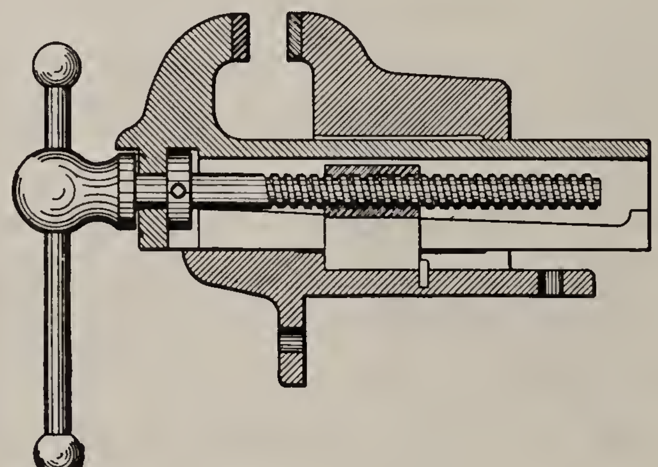


***Fig. 46.** Sectional view of typical heavy-duty machinists' vise with very high jaws and long arm. The deep throat and wide opening allow the operator a maximum amount of room for holding work.*

this inertia as to supply strength against rupture. It is of course essential that a vise is strong enough to withstand any strain that may normally be put upon it.

Numerous workbenches supplied by various manufacturers are equipped with one or more built-in vises to facilitate the fastening

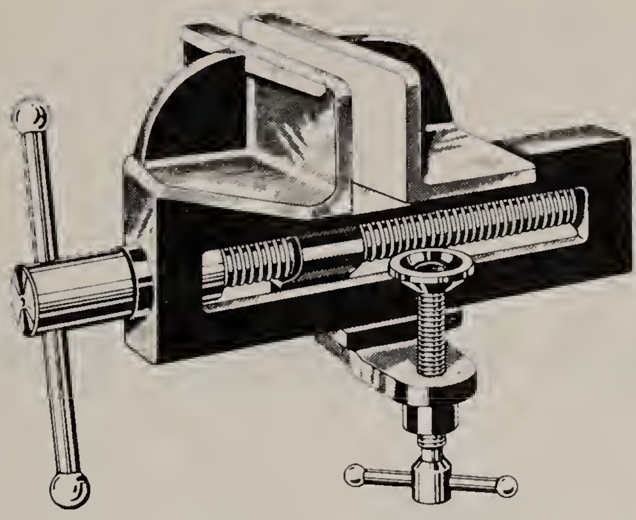


Fig. 47. Sectional view of woodworkers' vise suitable for medium-duty service.

of the work to be drilled, sawed or planed. This type of vise (Fig. 47) is intended for use in connection with wood processing only and should not be employed for metalwork because this may impair its future usefulness. Only the machinists' vise or specially adapted vises should be used for holding metal.

CHAPTER 4

Hand Tools for Cutting

One of the main reasons for poor results in woodworking is the use of dull cutting tools, that is, neglect in keeping tools sharp. Not only should the cutting edge be whetted or honed as soon as any sign of dullness is observed, but the tools should always be kept perfectly clean and free from rust. Sharp-edged cutting tools may be divided into several classes, such as:

1. Chisels
2. Planes
3. Hatchets and axes
4. Drawknives
5. Miscellaneous

Chisels—The chisel is an indispensable tool in any woodworking operation, and a full assortment is a prime necessity in any well-equipped shop. A chisel is used in cutting wood surfaces and consists essentially of a flat piece of steel with one end ground to an acute bevel to form a cutting edge, and the other end pro-

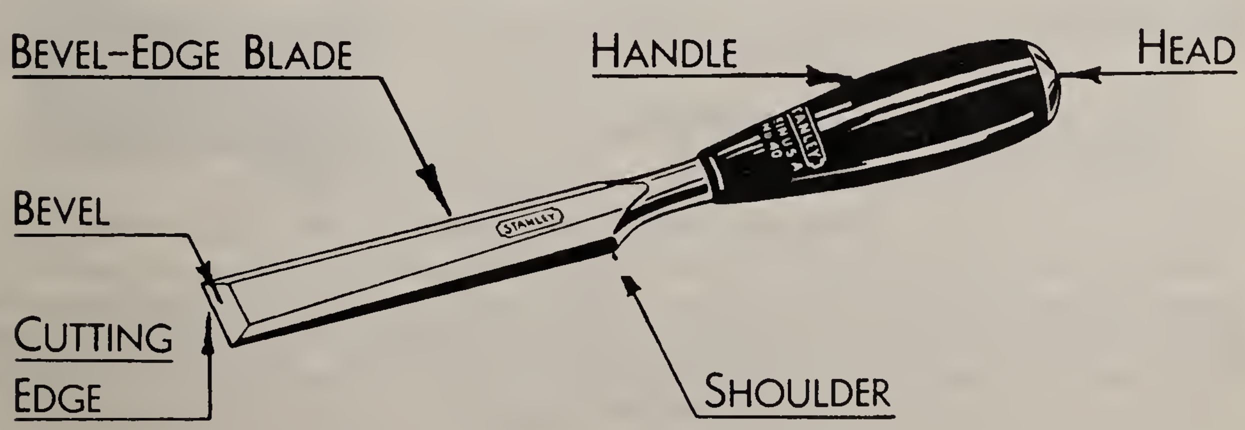


Fig. 1. Typical general-purpose wood chisel with handle of black plastic possessing unusual resistance to breakage.

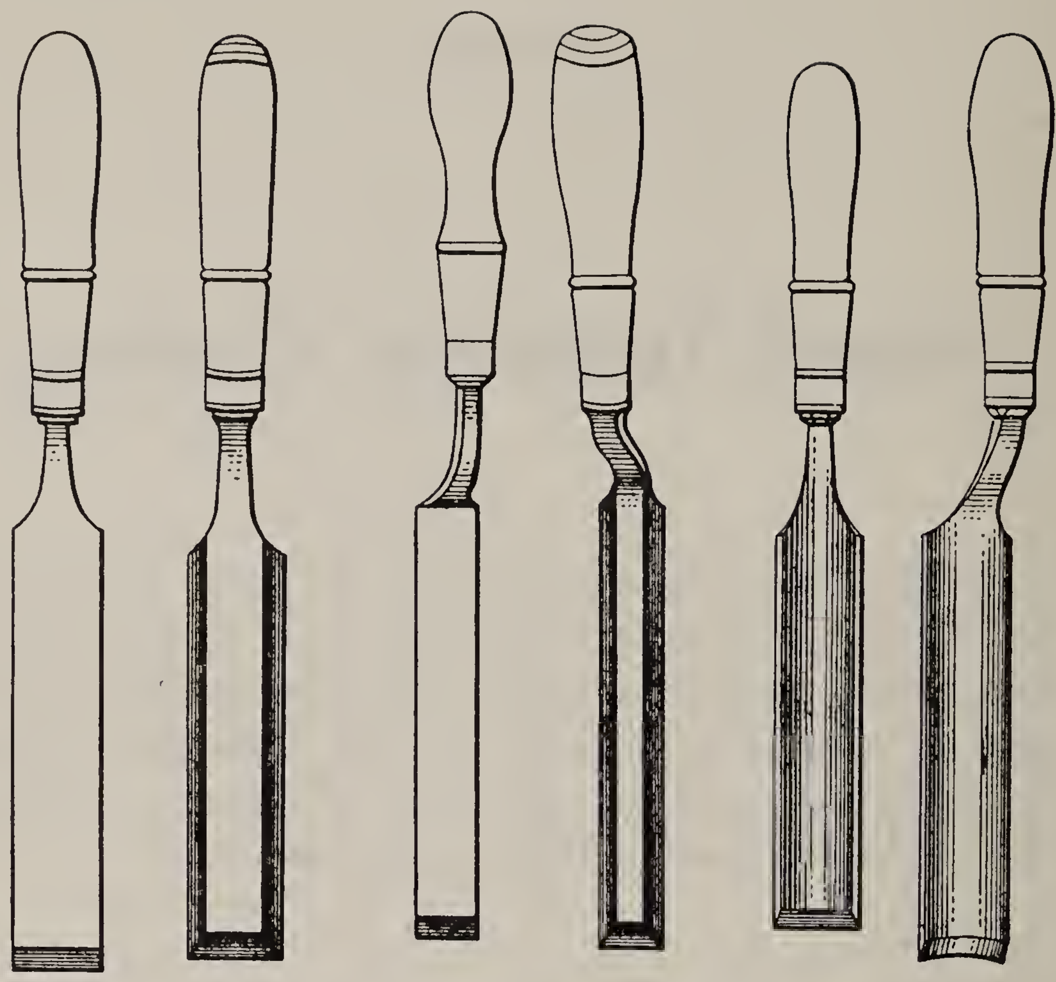


Fig. 2. Various types of framing chisels and gouges.

vided with a wooden or plastic handle. Chisels are named according to their duty or service, as: paring, firmer, mortise, gouge, etc.,

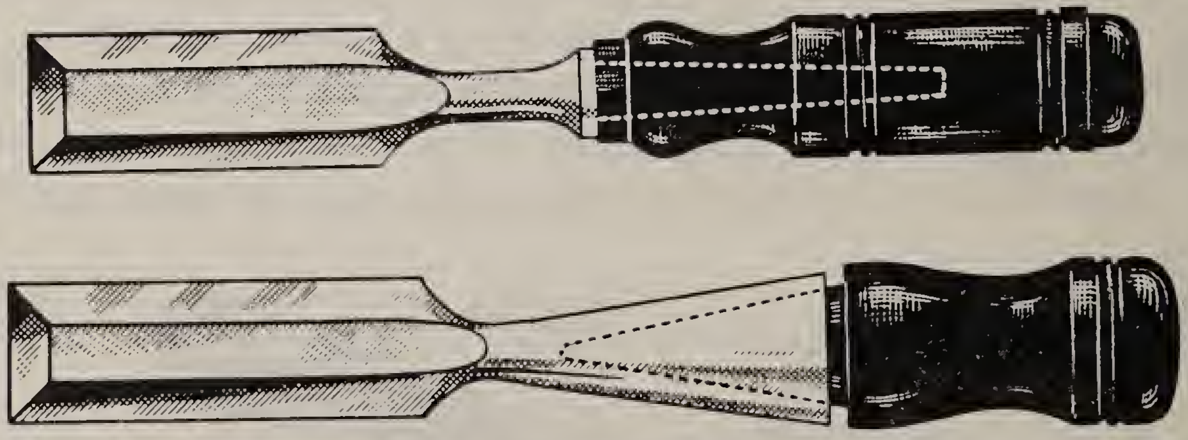


Fig. 3. Typical tang-and-socket chisels respectively. The terms "tang" and "socket" are derived from the fact that the shank of the tang chisel has a point that is fitted into the handle. This point is called a tang, hence the name "tang chisel." In the socket chisel, the shank of the chisel is made like a cup or socket with the handle fitted into it. Thus the chisel is called a "socket chisel."

or, with respect to the method of attaching the handle, as tang or socket (Fig. 3).

The paring chisel is a light-duty tool for shaping and preparing relatively long planed surfaces, especially in the direction of the grain of the wood. The paring chisel (Fig. 5) is manipulated by a steady sustained pressure from the hand, not driven by blows.

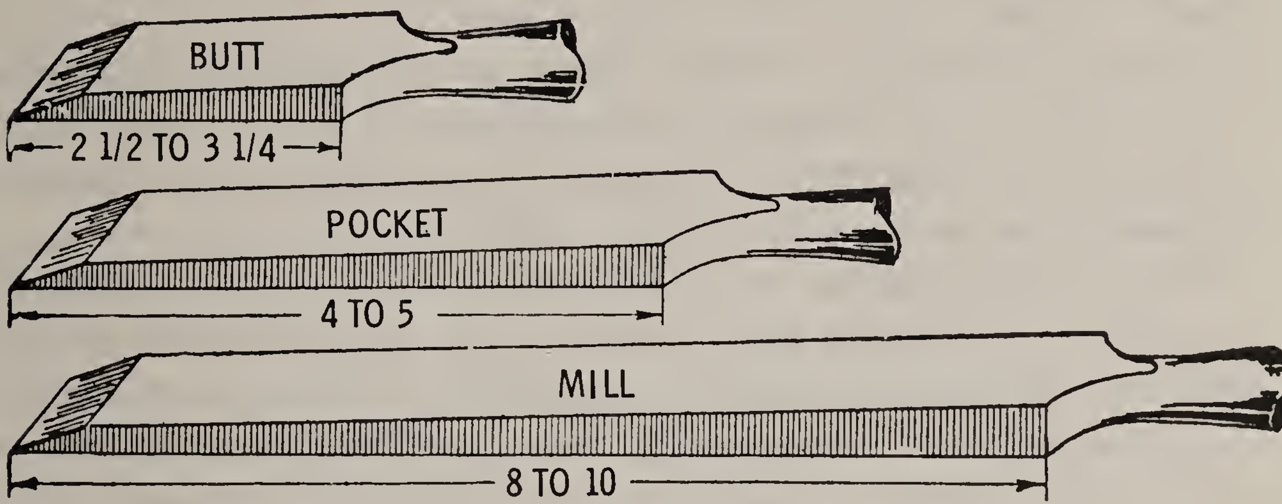


Fig. 4. Wood chisels classified with respect to length of blade. The blade width may vary depending upon the kind of work to be performed.

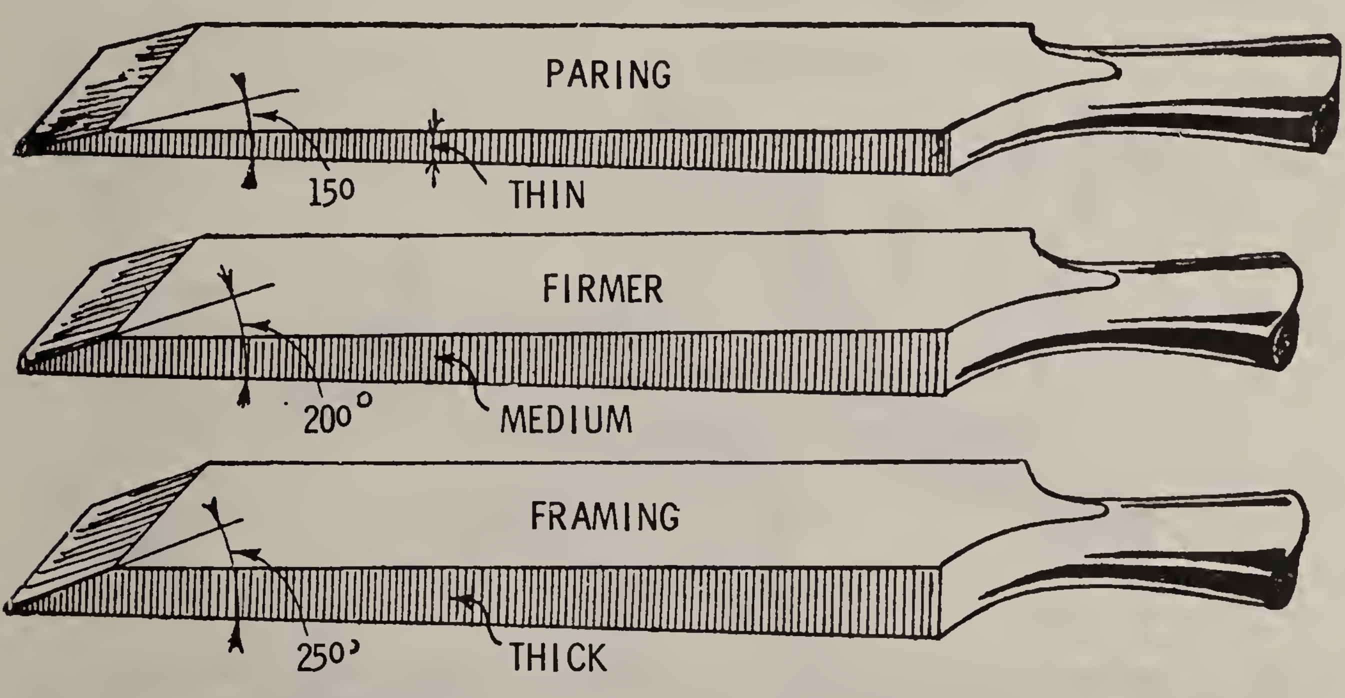


Fig. 5. Various chisels classified with respect to duty. They are classified as paring or light duty, firmer or medium duty, and framing, or heavy duty.

The firmer chisel as the name implies is a more substantial tool than the paring chisel, and is adapted to medium-heavy duty. The firmer chisel (Fig. 5) is a tool for general work and may be used for paring or light mortising, being driven by hand pressure in paring and by blows from a mallet in mortising.

The mortise or *framing chisel* is a heavy-duty tool adapted to withstand severe strains required in framing and carpentry work where deep cuts are necessary. In the best construction, an iron ring is fitted to the end of the handle to prevent splitting, thus permitting the use of a heavy mallet in driving the tool into the wood.

The gouge chisel is provided with a curved, hollowed blade and is used for scooping or cutting round holes. There are two kinds of gouge chisels: namely, the outside and inside bevel type, of which the outside bevel is the more common.

The corner chisel has an L-shaped blade and is used in clearing out corners and angles (90° and over), in squaring holes, and in general for a V-cut required in pulley stiles or in hand-rail moldings. For driving chisels, a hammer or other metal tool should never be used—only a mallet. It has been found by experience that wood-to-wood contact is the only satisfactory method for driving chisels. An exception to this rule is the framing chisel when it is equipped with a special handle.

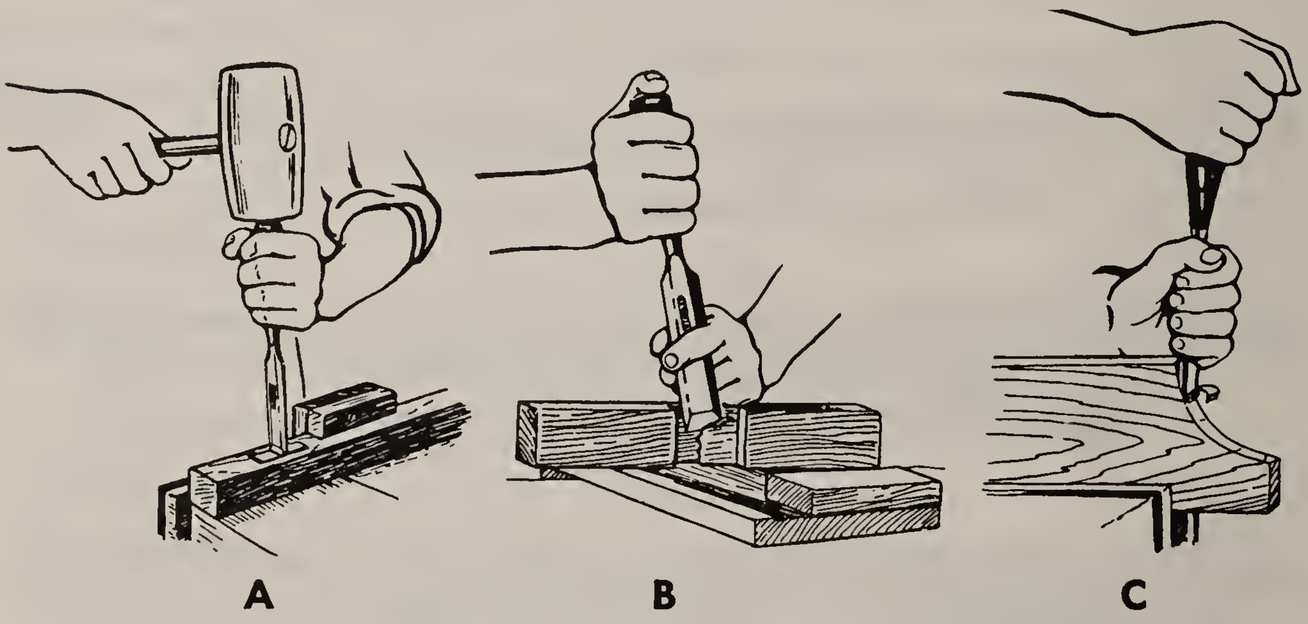


Fig. 6. Method of using chisels for various kinds of work. (A) the use of a firmer chisel for light mortise work; (B) the use of paring chisel; and (C) method of cutting a concave curved corner. In mortise work, the back of the chisel should be kept perpendicular and across the grain of the wood. In medium and heavy mortise work, the bulk of the material is usually bored out, after which the chisel is used to remove the shoulders as required for a completely square or rectangular cut.

The best chisels are made of selected steel with the blade widening slightly toward the cutting edge. The blades are oil tempered and carefully tested. The ferrule and blade of the socket

chisel are so carefully welded together that they practically form a single piece. Beveled edges are preferable to plain blades because they tend to drive the tool forward and have greater clearance.

Planes—A woodworking plane consists essentially of a smooth-soled stock of wood or iron, from the underside or face of which projects slightly the steel cutting edge. The cutting edge of a plane, which inclines backward, is called the plane iron. An aperture in the front provides for the escape of shavings.

Woodworking planes are tools which are used for smoothing boards or other surfaces, for forming moldings, removal of surplus wood and the like. Thus, the plane is essentially a finishing tool and, while it is adapted for bringing wood surfaces to the desired thickness, it will produce this result only gradually as compared to a chisel or hatchet. There are a great number of different-sized planes suitable for various services, such as:

1. Jack plane
2. Fore plane
3. Jointer plane
4. Smoothing plane
5. Block plane
6. Molding plane
7. Rabbet plane
8. Spokeshaves, etc.

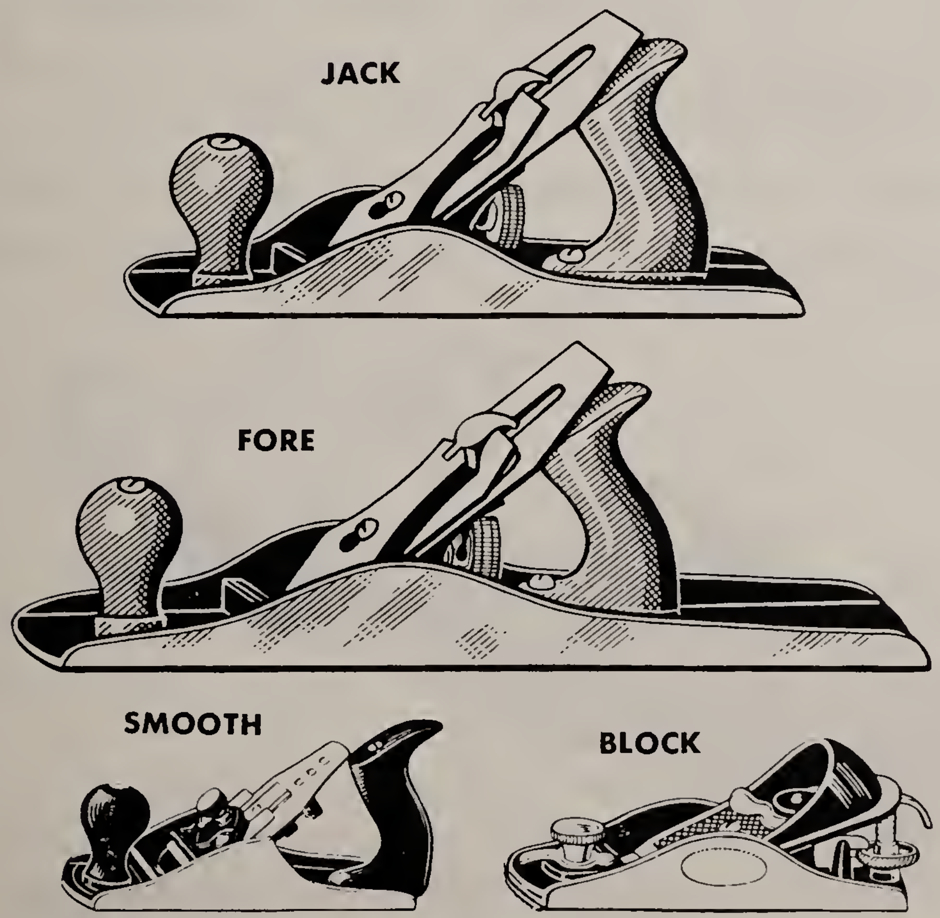


Fig. 7. Various types of planes used by woodworkers.

Hand Tools for Cutting

A jack plane is used for coarse work, such as the preparation of the work for use of a jointer or fore plane. It is from 11 inches to 15 inches in length; thus it is long and heavy enough to make it a powerful tool for removal of considerable material on each cut. The cutting edge of the plane iron is slightly rounded, making it best adapted for roughing. If properly sharpened, the jack plane may be used as a smoothing plane, or as a jointer plane for small work, because it is capable of doing just as good work.

A fore plane may be described as a smaller jointer plane. It is about 18 inches in length and may be used to straighten and smooth irregular cuts of a jack plane. Since the fore plane is shorter than the jointer plane, it is easier to handle and may be used in the same manner as a jack plane. The plane iron of the fore plane is sharpened to a straight line and is set for a finer cut than that of a jack plane.

A jointer plane is a long finishing plane from 22 to 24 inches in length and is used to cut long straight surfaces and to true the edges of boards to be accurately joined. The length of the plane determines the straightness of the cut. Thus, for example, a smooth plane, because of its short length, will follow the irregularities of an uneven surface, taking its shavings without interruption. A fore or jointer plane similarly applied on an uneven surface will first touch only the high spots, progressively lengthening the cuts until upon reaching the lowest spots a continuous shaving will be taken.

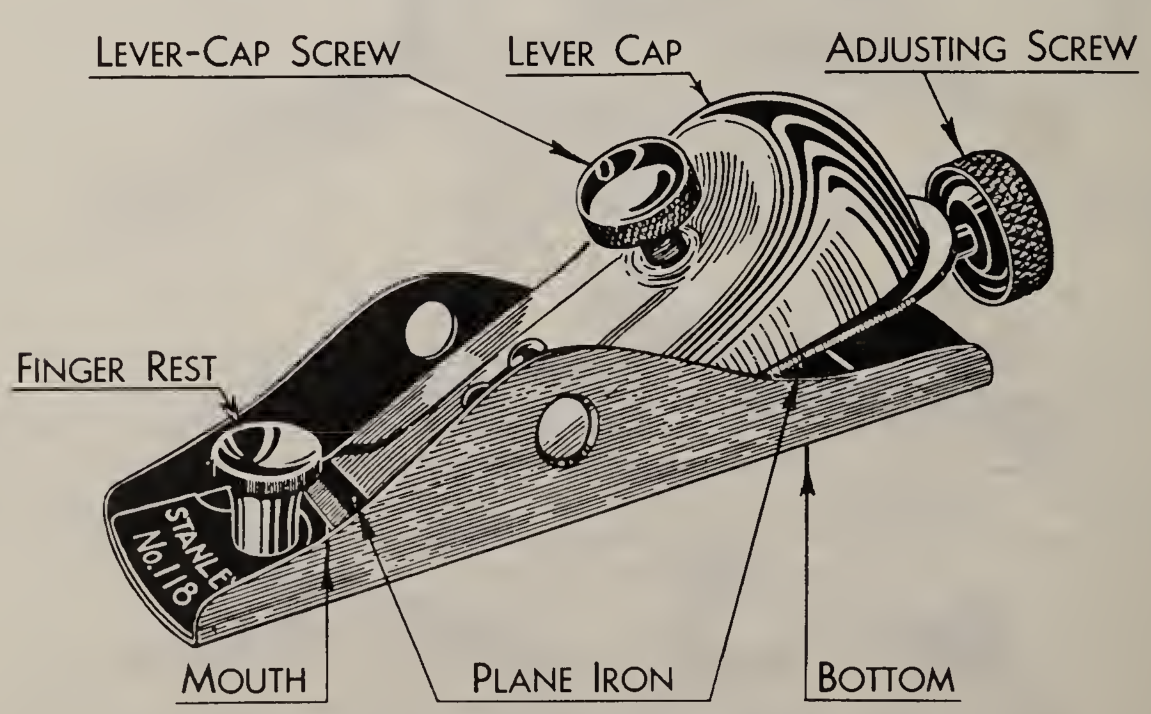


Fig. 8. Typical block plane and component parts.

The final cut will approach a true plane surface in degree depending upon length of the tool and length of irregularities or undulations of surface originally present. The cutting edge for a jointer plane is ground straight and set for a fine cut.

A block plane is used for planing across the grain, particularly the ends of boards. It is one of the smaller planes and may be purchased in lengths of from 4 inches to 7 inches. It was designed to meet the demand for a plane which may easily be held in one

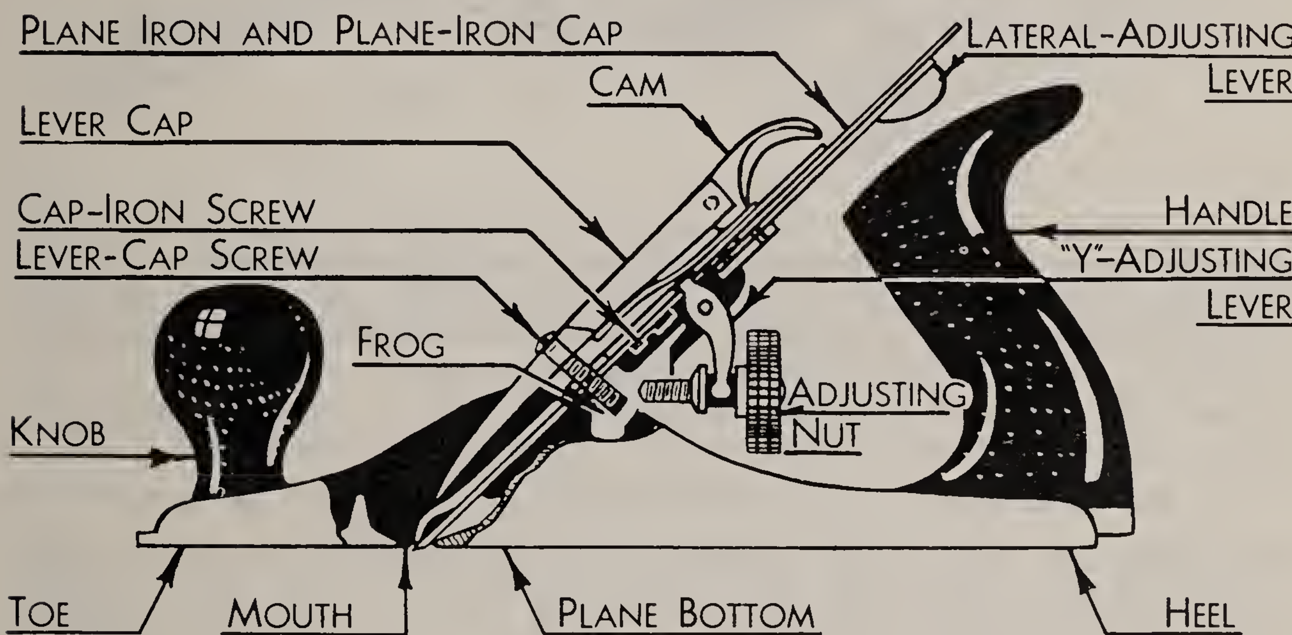


Fig. 9. Typical smooth plane and component parts.

hand while planing across the grain. Since it is used almost exclusively for planing across the grain, a cap iron is not necessary to break the shavings, as they are only chips.

In a plane of this sort, the plane iron is turned up instead of down. Because of its small size the block plane is usually operated with one hand, the work being held in the other; hence, as distinguished by this method of using, other planes are called *bench* planes.

A smoothing or smooth plane is a short, finely set plane about 8 inches in length adapted for smoothing and finishing work. Because of its small size it will find its way into minor depressions of the wood without taking off a large quantity of material. In this respect it differs from the fore and jointer planes. All three are finishing planes, but the fore and jointer planes are best for finer work.

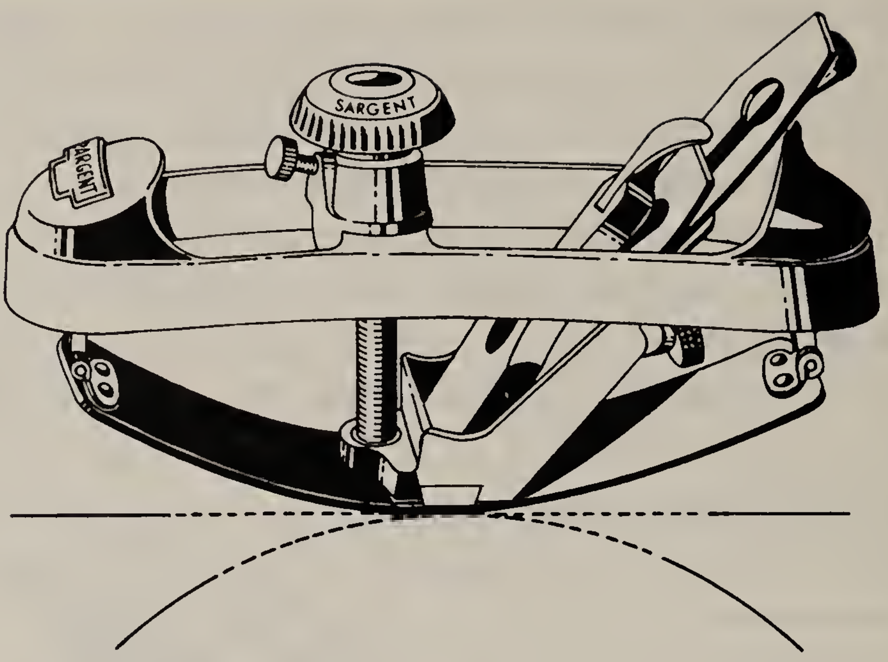


***Fig. 10.** Typical circular plane. In a plane of this construction, the flexible steel face may be adjusted to the required arc, either convex or concave, for planing curved surfaces and is accurately set and firmly held in position by the knob and setscrew.*

A molding plane as the name implies is designed to make various molding cuts, some planes performing only one and others a variety of operations. The following brief description, together with accompanying illustrations, will give a clear understanding of these various planes.

A rabbet plane is an open-sided plane, with the plane iron projecting slightly from the side as well as from the bottom of the plane. There are various forms of rabbet planes available, each suitable for different types of cuts. With a tool of this sort, the edge of a board can be cut so as to leave a rabbet or "sinking" like a step along its length to fit over and into a similar indentation cut into the edge of another board. Rabbet planes are adapted to cut *with* or *across* the grain according to the setting of the iron.

A universal or combination plane is used to produce a large number of moldings. Variously formed cutters may be inserted or exchanged as conditions require. It may also be used for tongue-and-groove work, slitting, and for sash work.

Plane irons perform their work in the same way as do chisels, but differ mainly in that their sides are parallel and the thickness is less. Standard plane irons may be of the single or double type depending upon the provision for breaking the chips. The heavy

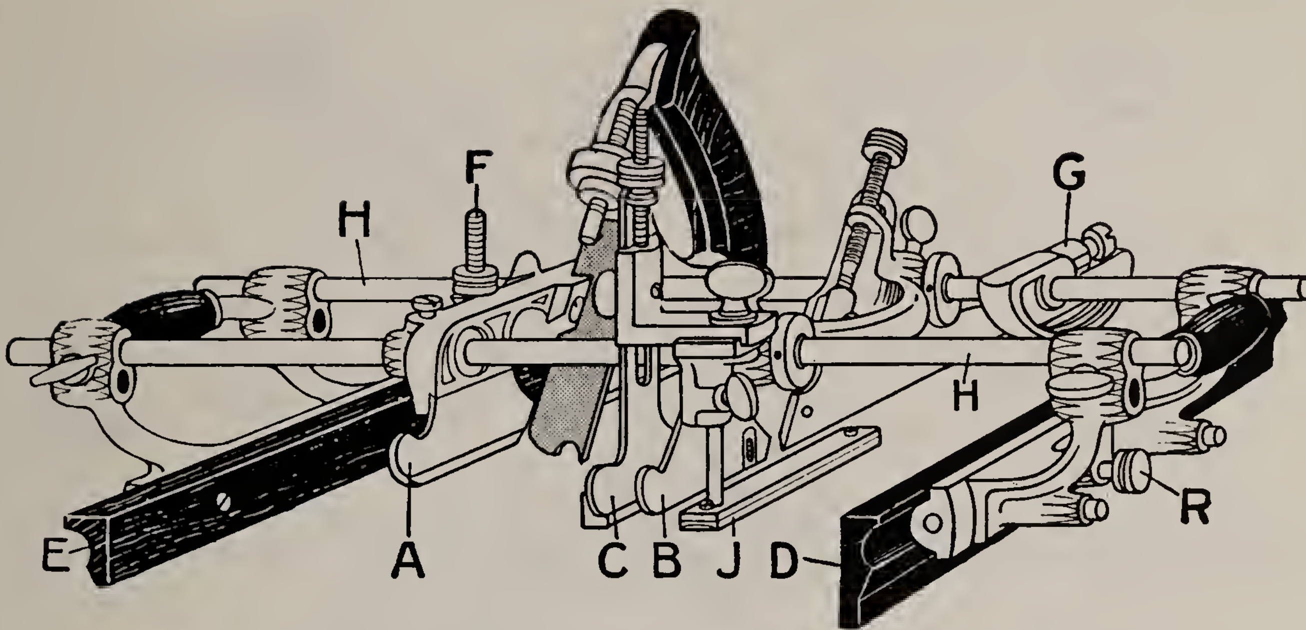


Fig. 11. Universal plane with description of parts. This plane may be used for several operations, such as plowing, dadoing, rabbeting, beading, reeding, fluting, rounding, hallowing, slitting, chamfering, and general molding. The plane consists of the main stock, A, which carries the cutter, cutter adjustment and cutter bolt, slitting tool, depth gauge and handle; B, the sliding section; C, the auxiliary center bottom; D and E, the fences; F and J, the gauges; H, the arms for carrying the fences and G, the cam rest.

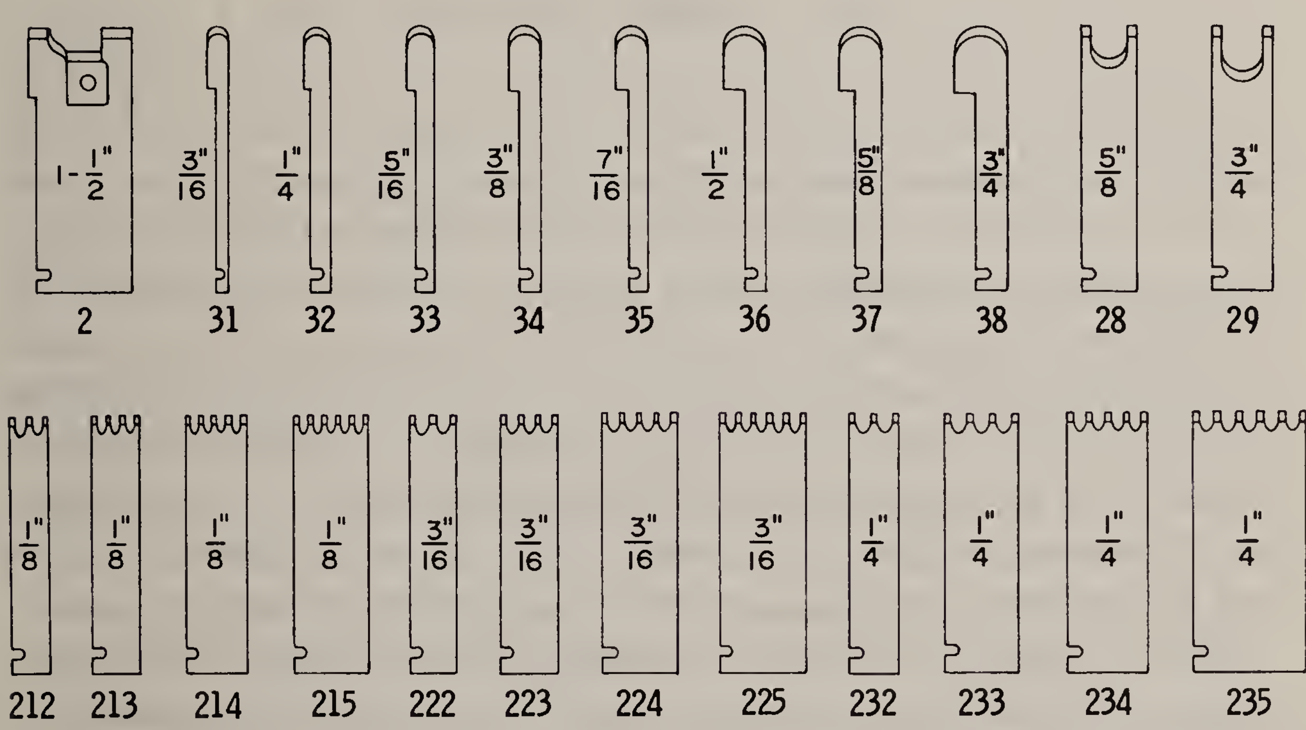


Fig. 12. Some of the cutters used with the universal plane.

plane irons are usually No. 12 gauge, whereas the medium or thin plane irons are No. 14 gauge. The heavy plane iron offsets the tendency found in spring-cap planes to vibrate; the additional weight helps to avoid chattering.

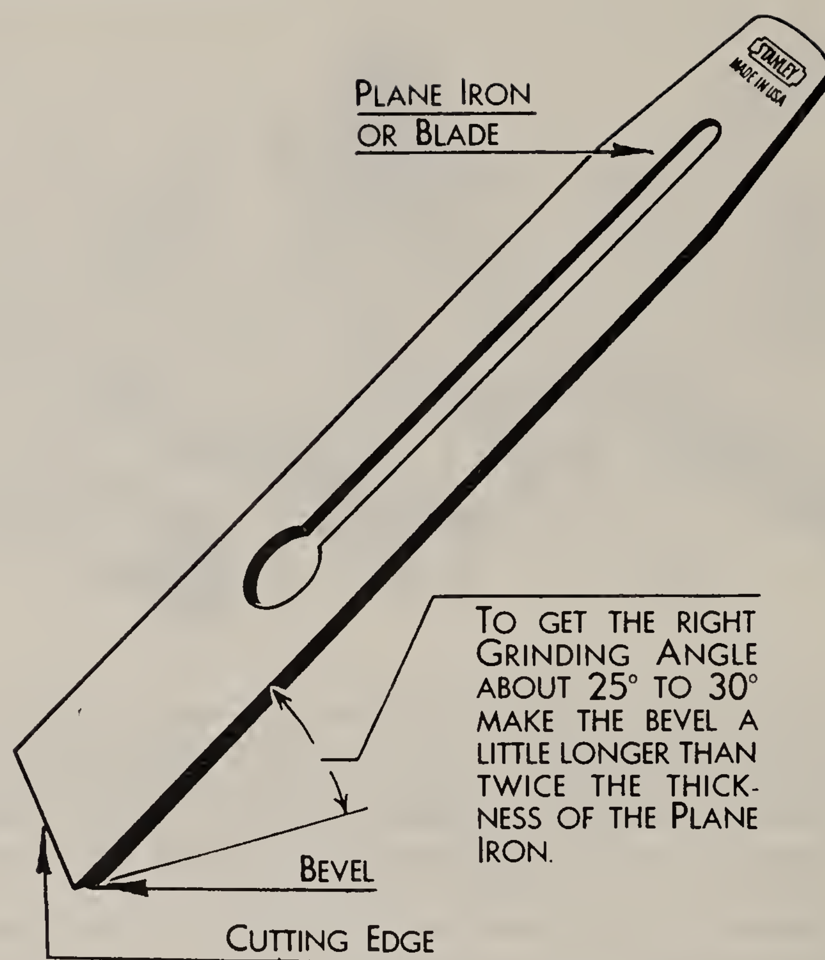


Fig. 13. Single plane iron.

The thin plane iron is usually satisfactory when the plane is properly constructed so that firm support is given the plane iron over a considerable portion of its length. It also has the advantage of requiring less grinding. Since plane irons differ with respect to their cutting edge, the jack plane has its edge ground slightly curved or hollow-ground as noted in Fig. 14. This is because it is used to remove thick shavings. If the iron were ground straight, the plane would cut a rectangular channel from which the wood would have to be torn as well as cut. Such a shaving would probably stick fast in the throat, or the plane would be extremely hard to push.

When a full set of planes is available, the fore plane should have some curvature to the cutting edge. In this case the process of transforming the grooved surface produced by the jack plane to a flat surface is accomplished in three operations, using jack, fore, and smooth or block planes as conditions dictate.

The cutting edges of the jointer and smooth-plane irons are made straight with slightly rounded corners. Because these planes make a very fine cut, the groove caused by the removal of a delicate

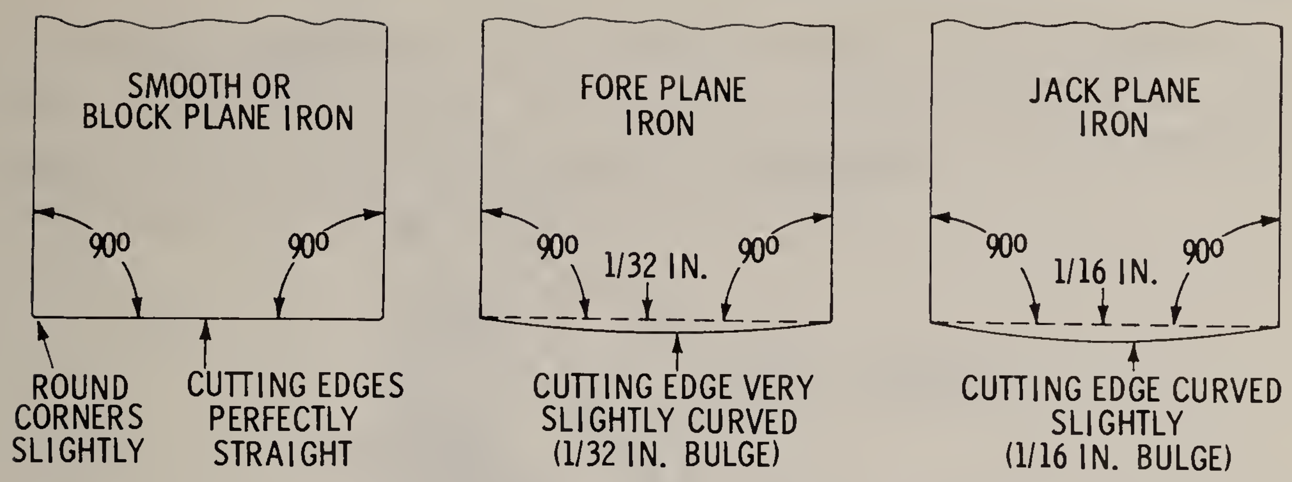


Fig. 14. Cutting edges for common plane irons. Cutting edges should be straight on smooth and block plane irons, and very slightly curved on jack and fore plane irons.

shaving is sufficiently blended with the general work by the rounded corners of the iron.

The larger plane irons are equipped with a supplementary iron called a *plane-iron cap.* The object of the plane-iron cap is to assist in breaking the shaving as quickly as possible after it is cut. The plane-iron cap as noted in Fig. 15 is attached to the iron by tightening a screw which passes through a slot in the cutting iron. The distance at which the plane-iron cap is placed from the edge of the iron varies with the thickness of the shaving. It is customary to allow 1/32 in. for smooth or fore plane, and about 1/16 to 3/32 in. for a jack plane.

How to Use a Plane—To obtain satisfactory results with planes, it is necessary to know not only the proper method of handling the tool when planing but also how to keep it in good working condition. Accordingly, the user must know, not only how to grind, whet, and adjust the iron, but also how to use it properly. Satisfactory results in the use of a plane depend largely on the plane being in perfect condition and properly adjusted as to "set" and depth of cut to suit the kind of wood being planed.

The first thing to learn is the correct way of holding the plane. Do not allow the plane to tilt over the end of the board at either end of the stroke. Before planing, examine the board with respect to the grain and turn the board so as to plane with the grain. On the return stroke, lift the back of the plane somewhat so that the plane iron will not rub against the wood. This prevents the plane iron being dulled quickly. This procedure is important on large

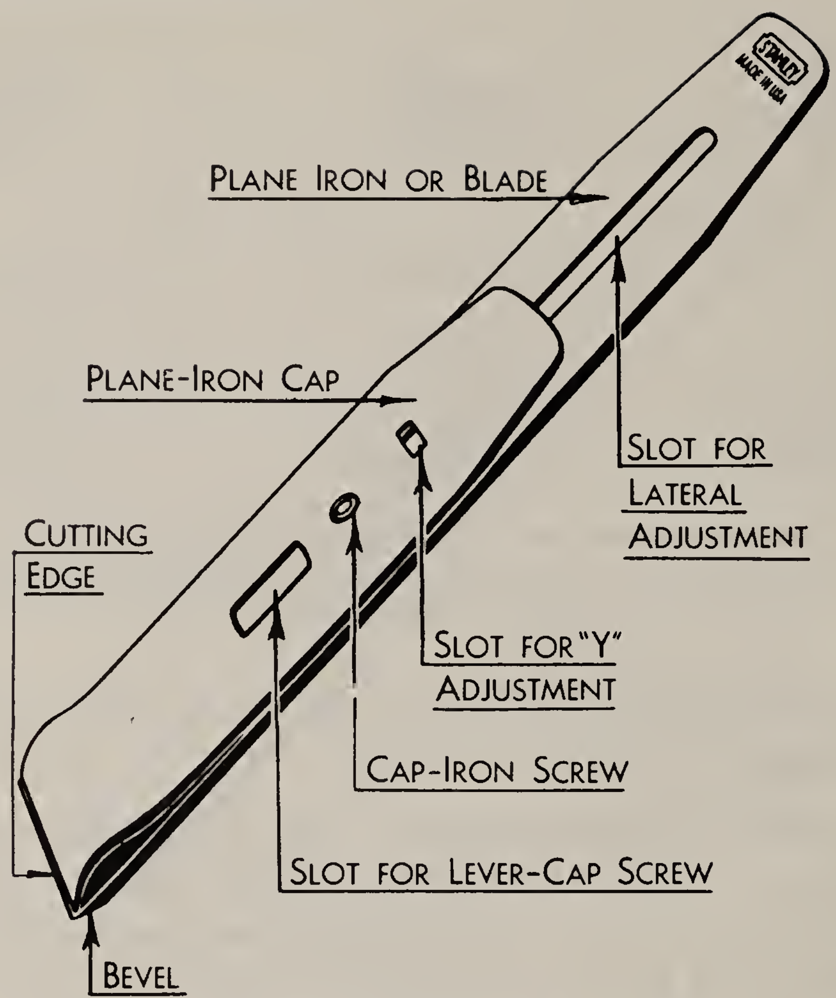


Fig. 15. Double plane iron.

surfaces especially when they are rough. The plane iron moves more easily and smoothly when the plane is held at a slight angle.

In planing a narrow surface, let the fingers project below the plane and press against the side of the board as a guide to keep the plane on the work. Should the plane choke with shavings, look for the cause instead of just removing them. Remove the iron and examine carefully the edge of the plane iron cap. This must be a perfect fit, otherwise there will be continuous trouble.

In planing a long surface such as a long board, begin at the right-hand end. Take a few strokes, step forward and take the same number of strokes, progressing this way until the entire surface is planed. In cutting across the grain with a block plane, the cut should not be taken entirely across the board. The plane should be lifted before the plane iron reaches the edge of the board, otherwise the wood will split at the edge. After taking a few strokes, reverse the board and continue until the desired result has been obtained.

Hatchets and Axes—Hatchets and axes are tools familiar to every woodworker. The hatchet is a combination hammer and cutting tool and is used largely for sharpening stakes, splitting wood, and other rough work.

Fig. 16. Typical hatchets and axe.

The hand axe is simply a large hatchet with a broad cutting edge. Ordinarily it is held with the right hand at about one-third the distance from the end of the handle, but the position of the hand will be regulated to a great extent by the material to be cut, that is, by the intensity of the blow. The axe is similar to the hand axe but its larger size and longer handle are designed for two-handed use for the heavy cutting of which it is capable.

Drawknife—This tool consists of a large sharp blade having at each end a handle at right angles to the blade. It is used for trimming wood and is drawn toward the user. When properly sharpened and when some degree of force is applied, it does its work quickly and efficiently. This tool was formerly used to a large extent in the rapid reduction of wood to an approximate size, an operation that is presently performed by sawing or planing machinery. It is, however, a very effective tool on narrow surfaces that must be reduced considerably.

Miscellaneous—An assortment of sharp-edged cutting tools other than those named, along with a number of abrasives, are essential in the workshop.

A cabinet scraper is used for final smoothing before sanding. It removes the slight ridges left by the plane. It is also used on

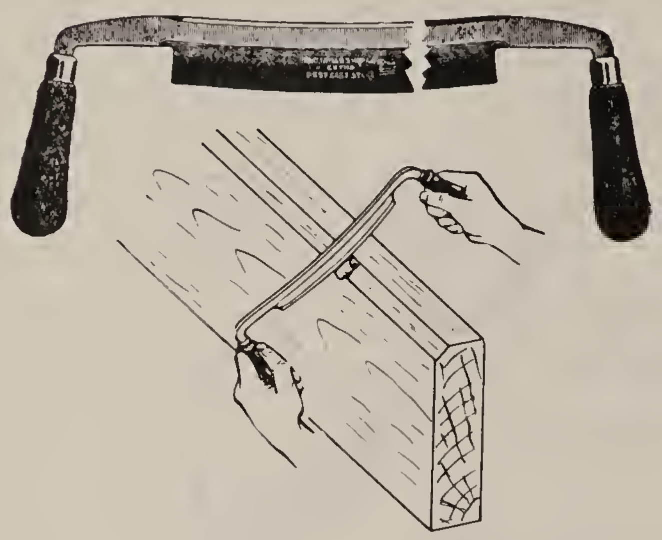


Fig. 17. Typical drawknife and method of use.

smooth surfaces that are difficult to plane because of curly or irregular grain.

To adjust or set a cabinet scraper, loosen the adjusting thumbscrew and the clamp thumbscrews. Insert the blade from the bottom with the bevel toward the adjusting thumbscrew. Bring the edge of the blade even with the bottom of the scraper body by

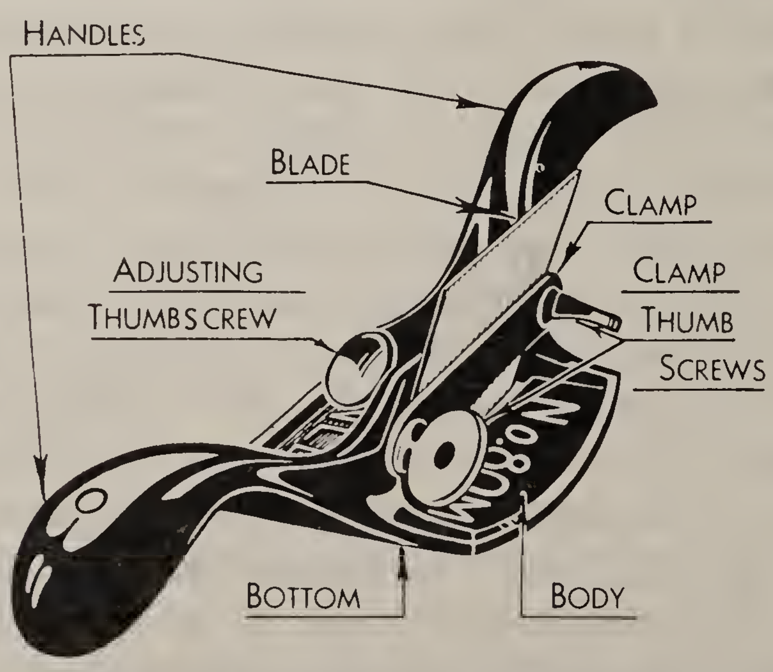


Fig. 18. Cabinet scraper. In working, the blade springs backward, opening the mouth and allowing shavings to pass through. As soon as the working pressure is released, the blade springs back to its normal position.

standing the scraper on a flat wood surface and pressing the blade lightly against the wood. Tighten the clamp thumbscrews. Bow the blade by tightening the adjusting thumbscrew so that the blade projects enough to take a thin shaving. If one corner of the blade projects too far, it can be drawn in by tapping that side of the blade near the top.

A hand scraper is used for the same purposes as the cabinet scraper. In operation, the hand scraper can be either pushed or pulled as the grain of the wood demands, or whichever is more convenient. It is held firmly between the thumb and finger at an angle of about 75 degrees and curved slightly by thumb pressure.

A spokeshave is similar to a plane with the bottom short enough to follow curves. In operation, the spokeshave is pushed along the wood in the same manner as any other woodworking plane. The flat-bottom spokeshave is used on convex and concave surfaces

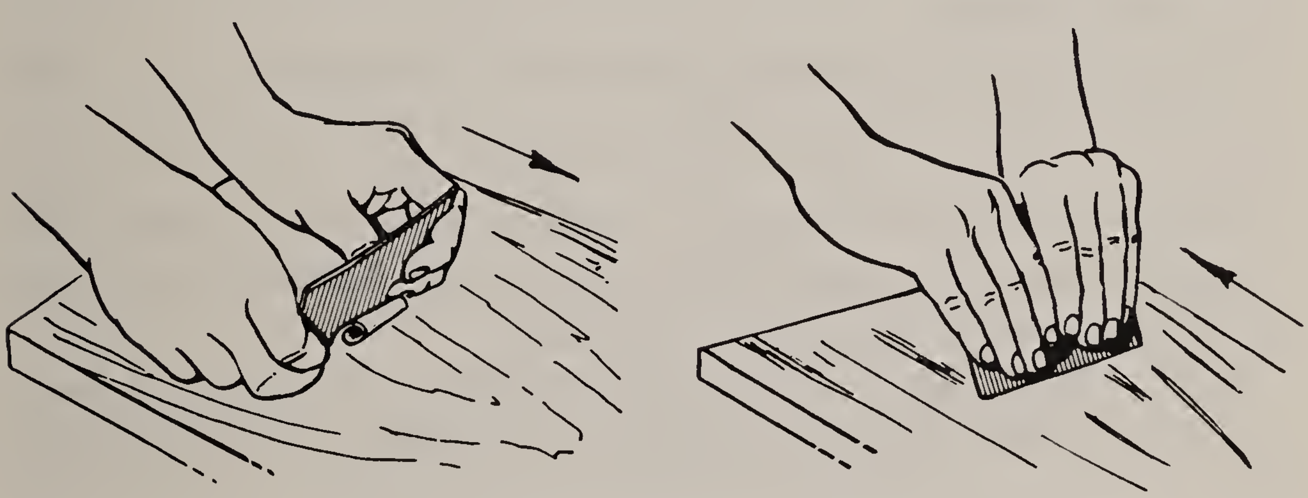


Fig. 19. Hand scraper and methods of use. In operation, the hand scraper is pushed or pulled, removing surface irregularities in the work and when properly used provides a smooth and glossy finish.

where the curves have a long sweep. It is also used to chamfer or round edges. The hollow-bottom or concave-bottom spokeshave is used for rounding edges having small convex sweeps, whereas the convex-bottom spokeshave is designed to cut concave curved edges having small sweeps.

To set a spokeshave which does not have adjusting nuts, gently tap the end of the blade to make it project the thickness of a hair. To adjust the blade laterally, in order to take an even shaving, tap it on the side that projects too much. After the foregoing adjustments, tighten the cap screw with a screwdriver.

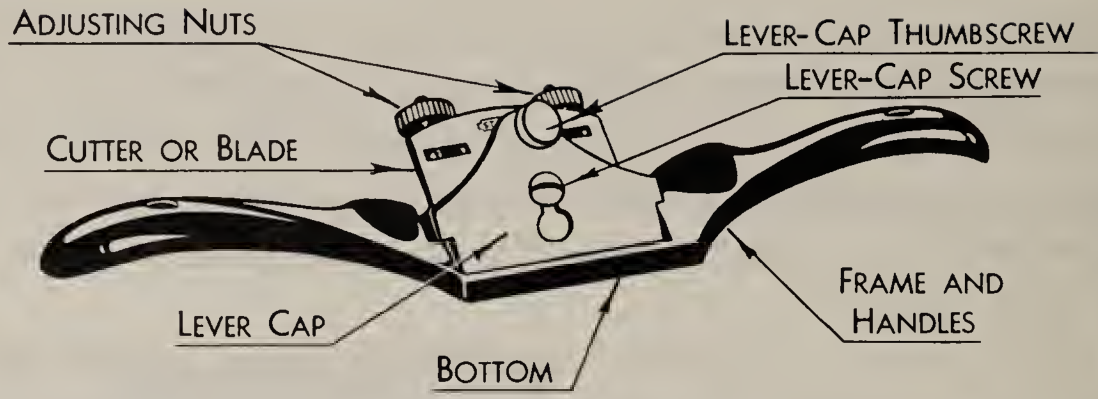


Fig. 20. Typical spokeshave. This is a light, handy tool for use on concave, curved edges having small or large sweeps. The wing-nut adjustment is on the cutter cap.

Among the large variety of *abrasives* presently on the market, common sandpaper or *flint* paper is perhaps the most widely used. This consists essentially of a tough sheet of paper covered with finely crushed abrasive material. The paper used is made especially for this purpose from old manila rope, which produces paper of very great strength.

The glue used in sandpaper manufacturing is practically all animal-hide glue of the best quality, as it is necessary to have the grains of sand not only firmly but rigidly anchored to the sheet. Ordinary commercial sandpaper is made with crushed quartz rock, which is hard and sharp. Sand from the sea or beach is never used, as the sharp edges have been worn dull.

For sanding machine use and particularly for hardwoods, *garnet* paper rather than flint paper is used, as it is harder and lasts longer.

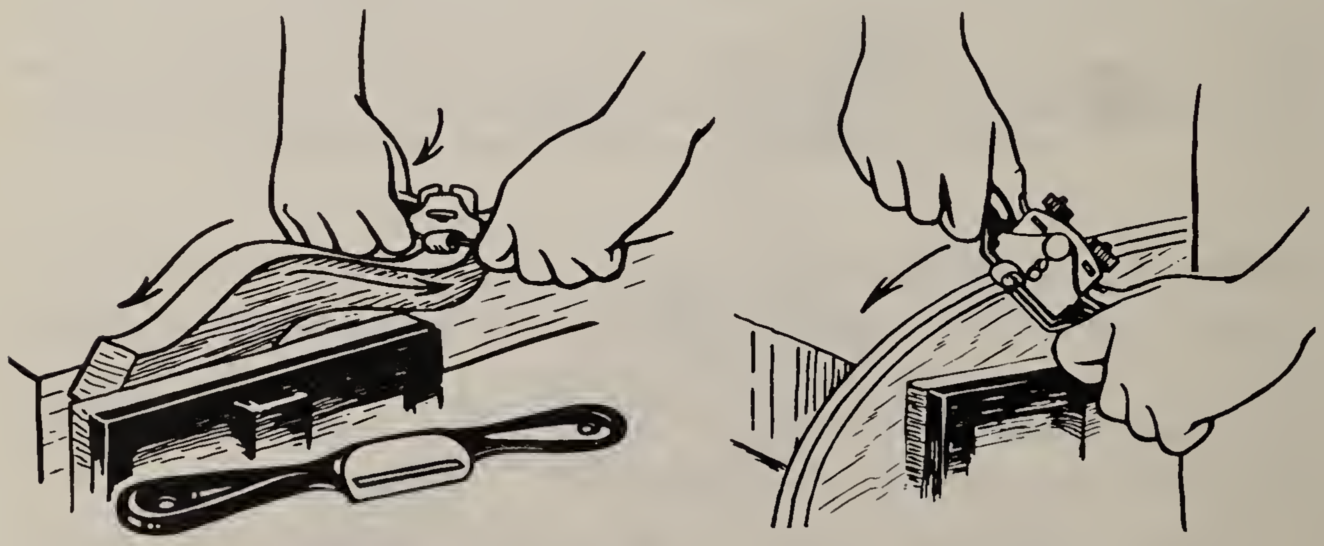


Fig. 21. Method of using spokeshave. The spokeshave cuts when pushed away from the user as indicated by the arrow. In using the spokeshave, be careful to work in the direction in which the tool cuts without tearing the grain. As noted in the figure, the spokeshave is also used to chamfer and to cut edges.

Most of the garnet, which is brown to red in color depending upon the size of the grit, comes from the Adirondack Mountains in the state of New York, where it occurs in pockets in the rock. The rock and garnet are crushed together to a small size and the garnet separated on specially constructed ore-separating tables.

Artificial abrasives are a product of the electric furnace and are widely used in the trades for various buffing and grinding operations. The two main groups of artificial abrasives are the aluminum oxide and silicon carbide.

Aluminum oxide is made by fusing bauxite, a highly aluminous clay, in an electric-arc furnace at about 3,000° F. Silicon carbide is made by fusing sand and coke at high temperature. The silicon carbide crystals are next in hardness to a diamond but are rather brittle as compared to aluminum oxide crystals.

Both aluminum oxide and silicon carbide are distributed under various trade names such as Aloxite, Alundum and Lionite (all aluminum oxide) and Carborundum, Crystolon and Carsilon (all silicon carbide). The grain size or grit of these artificial abrasive products is determined by passing the crushed ore over a wire or silk screen. The number of holes per inch of screen obviously determines the size of grain. Thus, for example, grains passed by a 24-mesh screen are called No. 24. In this manner, grain sizes from No. 6 to No. 240 are obtained. Since it is difficult to make a screen of more than 240 meshes to the inch, finer grains of up to No. 600 are graded by an elaborate water flotation process.

TOOTHED CUTTING TOOLS

Cutting tools may be divided into several groups or classes depending upon their construction and use. Thus, for example, while the common handsaw may be termed a "toothed cutting tool," a chisel or plane is a sharp-edged cutting tool.

Saws—In almost every woodworking project the first cutting operation will be performed by a handsaw. There are many different kinds of saws, but the types of interest to the average woodworker may be classed as:

1. Crosscut.
2. Ripsaw.

3. Combined crosscut and ripsaw.
4. Back.
5. Compass.
6. Coping.
7. Hack.

Fig. 22. Typical handsaw used in various woodcutting operations. The size of a saw is determined by the length of the blade in inches, whereas the coarseness or fineness is determined by the number of points per inch. A coarser saw properly set is preferred for fast work on soft and green wood. A finer saw is suitable for smooth accurate cutting and for dry seasoned wood. Ripsaws commonly have 5½ and 6 points per inch, whereas, crosscut saws have 7 and 8 points per inch.

The crosscut saw is used to cut across the grain of wood and to cut wet or soft woods, whereas the *ripsaw* is used to cut wood with the grain. They are similar in construction, but ripsaws are slightly heavier, and they differ also in the rake of the teeth. The cutting edge of a handsaw is a series of small notches all of the same size. On a crosscut saw, each side of a tooth is filed to a

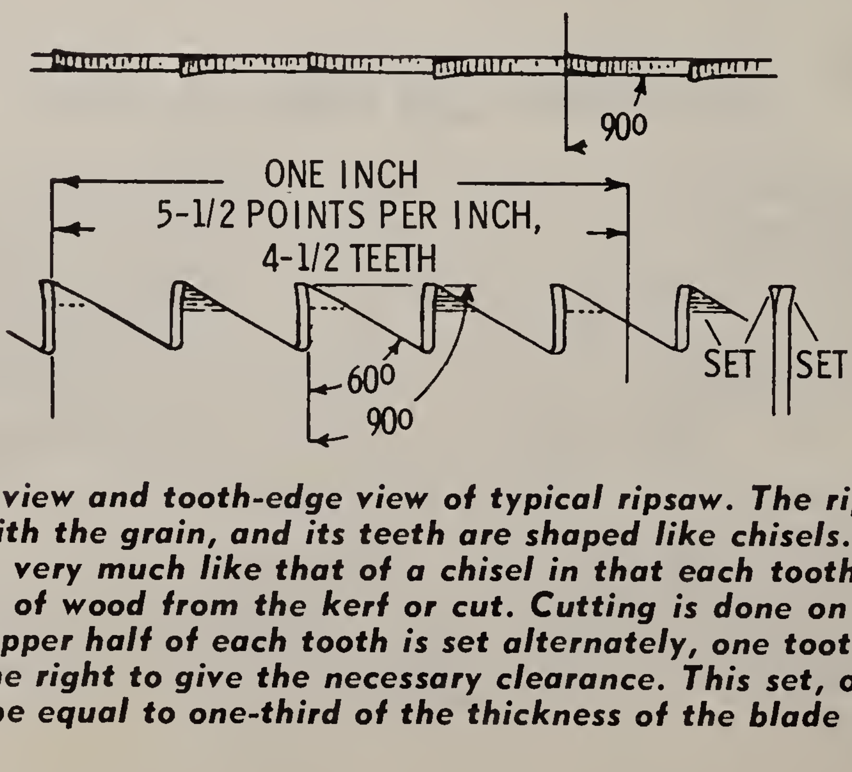


Fig. 23. Side view and tooth-edge view of typical ripsaw. The ripsaw is used for cutting with the grain, and its teeth are shaped like chisels. The cutting action is also very much like that of a chisel in that each tooth chips out a small portion of wood from the kerf or cut. Cutting is done on the forward stroke. The upper half of each tooth is set alternately, one tooth to the left and one to the right to give the necessary clearance. This set, on each side, should be equal to one-third of the thickness of the blade or less.

cutting edge like a small knife. On a ripsaw, each tooth is filed straight across to a sharp, square edge like a small chisel.

The set of a saw is the distance the teeth project beyond the side surface of the blade. The teeth are "set" to prevent the saw from binding and the teeth from choking up with sawdust. In setting, the teeth are bent alternately, one tooth to one side and

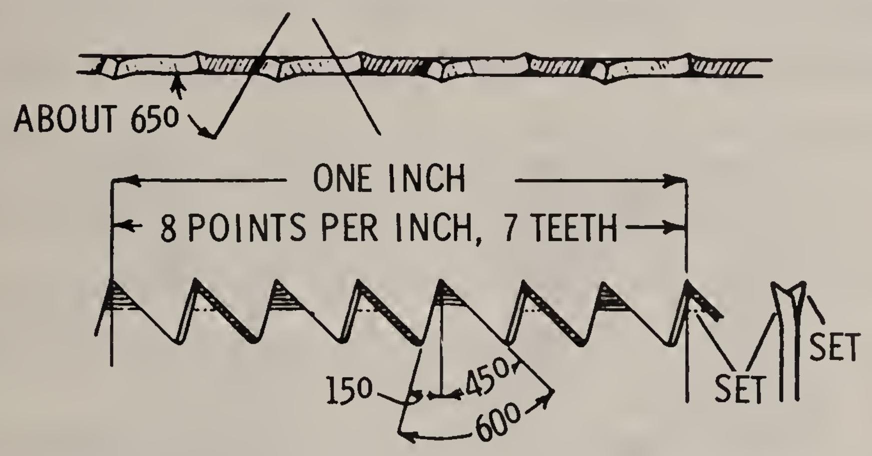


Fig. 24. Side view and tooth-edge view of typical crosscut saw. The crosscut saw is used for cutting across the grain and has a different cutting action than that of the ripsaw. The teeth cut like sharp pointed knives. They are also made with more points to the inch than the ripsaw. The crosscut saw cuts on both forward and backward strokes. The upper half of each tooth is set, alternately, one to the right, the next to the left to assure clearance.

the next to the other side, thus forming two parallel rows or lines along the edge.

The back saw is a thin crosscut saw with fine teeth and is stiffened by a thick steel web the entire length of the blade along its back. A popular size has a 12-inch blade length with 14 teeth or points per inch. It is used for making joints and in fine woodworking operations where great accuracy is desired.

The compass or keyhole saw has a small narrow blade with a pistol-grip handle and is commonly used for cutting along circular curves or lines in fine or small work.

The coping saw is also used for cutting curves or circles in thin wood, and consists of a small narrow blade inserted in a sturdy metal frame in a manner similar to that used in the hack saw.

The hack saw, although used primarily for cutting of metal, is a popular tool in any woodworking shop. There are two parts to a hack saw, namely, the frame and the blade. Common hack saws may have either adjustable or solid frames, although the adjustable frame is preferred. Hack-saw blades of various types

are inserted in these adjustable frames for different kinds of work. The blades may vary from 8 to 16 inches in length.

Solid frames, although more rigid, will take only the size of blade for which they are made. This length is the distance between the two points which hold the blade in place. The better frames are made with a pistol-grip handle, which greatly facilitates the application of pressure, particularly when sawing heavy metal objects.

Hack-saw blades are made of high-grade tool steel, properly hardened and tempered. There are two types, the all-hard and the flexible. All-hard blades are hardened throughout, whereas only the teeth of the flexible blades are hardened. Hack-saw blades are about ½ inch wide and have from 14 to 32 teeth per inch. The blades have a hole at each end which hooks to the frame. The tension of the blade is regulated by a wing nut.

How to Use a Ripsaw—When using a ripsaw place the board to be cut about knee height. The first operation before sawing is to mark the cutting line along the work. This marking is usually performed with a marking gauge. After this line has been marked, do not cut straight through the center of the line but along the side of it in the waste material. Start the cut with the finer teeth at the

Fig. 25. Proper position when cutting with ripsaw. Instead of using saw-horses, short pieces may be sawed by clamping the board securely in a vise or other holding device.

end of the blade and with a downward stroke. Put very little pressure on the saw until the kerf is well started. Then take long, easy

strokes. Do not force the blade at any time. This is not only tiring, but it also makes following the line more difficult.

In sawing wood, get well above the work so that the eye is on the same line with the saw blade and marking. The proper angle for ripping is 60 degrees between tooth edge and board. If the board is thin, lessen this angle to about 45 degrees. When ripsawing a long board, after a rip cut has been extended a few feet, the kerf may close sufficiently to cause the saw to bind. When this

Fig. 26. Approved method of crosscutting. As shown, an imaginary line through the saw, the arm and shoulder should be slightly to the left of the saw blade, permitting a clear view of the line of cut and action of saw and stroke. An angle of approximately 45 degrees should be maintained between the crosscut saw and the face of the work.

occurs, a small wedge inserted at the start of the cut will open the kerf sufficiently to prevent binding.

How to Use a Crosscut Saw—The use of a crosscut saw differs in some respects from the use of a ripsaw. While practically all rip cutting is on the forward stroke, the crosscut saw cuts on both forward and backward strokes. Before starting the saw cut make sure that measurements are exact and the mark for straight cutting is at a right angle to the length of the board. The best tool to use for this marking is a try square.

When starting the cut, place the saw at the side of the line to assure proper length. Start the cut near the handle of the saw, using a short draw stroke. Repeat slowly a few times until a slight groove is started, then cut with a full stroke. In crosscutting, it is best to maintain an angle of 45 degrees between the saw and the face of the work. Extending the forefinger along the side of the handle aids in guiding the blade. Take long easy strokes and make each stroke do its work.

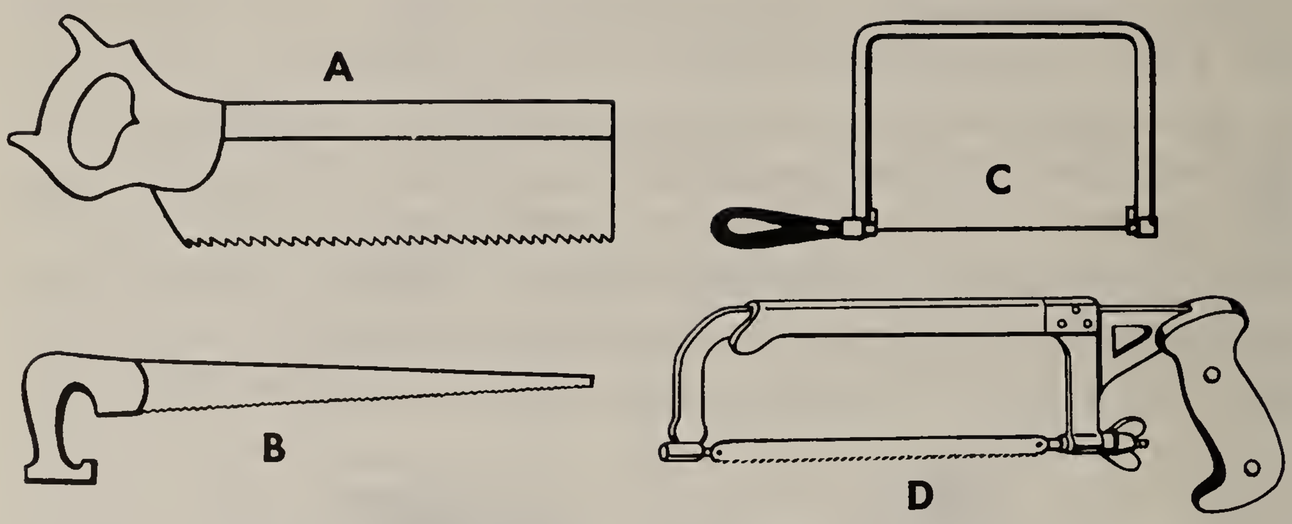


Fig. 27. In the figure, (A) represents a back saw; (B) compass saw or keyhole saw; (C) coping saw; (D) hack saw with pistol-grip handle.

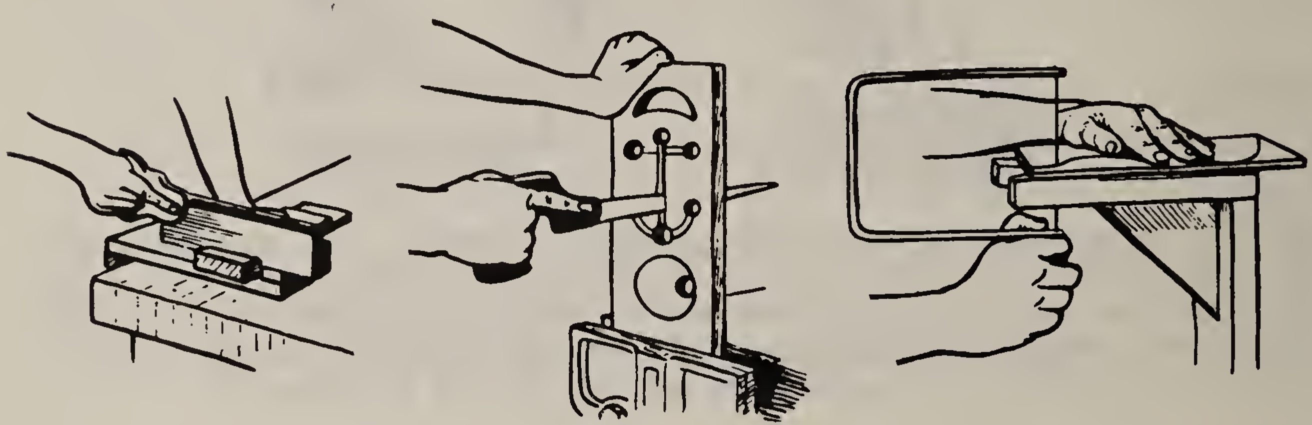


Fig. 28. Practical use of back saw, compass saw or keyhole saw, and coping saw. When using a saw, it is important that the work be properly fastened or clamped, otherwise, shifting of the work when sawing may easily cause blade breakage.

Files and Rasps—Files are hardened steel tools used for cutting, removing, or polishing various substances, such as metal and wood. The cutting edges or teeth on the surface are made by diagonal rows of chisel cuts. A rasp is a very coarse file and differs from the ordinary file in that its teeth consist of projecting points instead of diagonal rows of cutting edges.

Files are used by woodworkers for many purposes. Fig. 29 shows a variety of files and rasps. The taper file is intended for sharpening handsaws, pruning saws and bucksaws. The teeth of the mill file leave a smooth surface. They are particularly adapted to filing and sharpening mill saws, mowing and reaping cutters, etc.

Rasps are generally used for cutting away and smoothing wood or for finishing off the rough edge left in a circular hole cut with

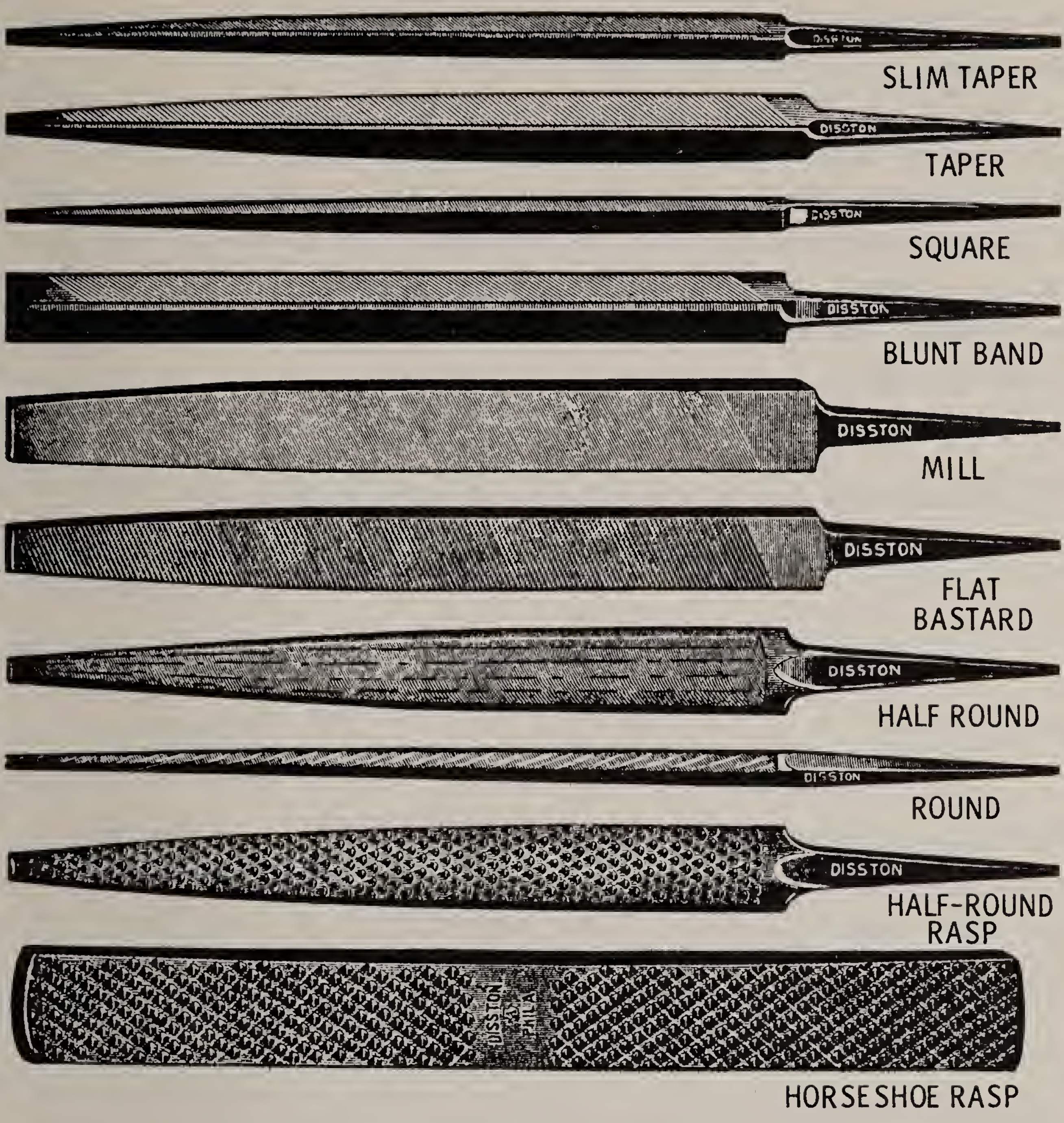


Fig. 29. Various types of files and rasps.

the coping saw. The common wood rasp is rougher or coarser than that used by cabinetmakers. Files for wood are usually tempered to file lead or soft brass and should never be used for any harder metal.

In drawing a file back between the cuts, do not allow it to drag, as it will be dulled. In using large rasps or files on wood or metal, the work should be held in the vise or otherwise firmly fixed, as it is desirable to use both hands when possible. The handle of the tool should be grasped by one hand while the other is pressed, but not too heavily, on the end or near the end of the blade so

as to lend weight to the tool and additional effect to its powers of abrasion.

One of the newest additions to the file family is the carbide grit file or rasp. It resembles other files in shape, but instead of having cutting teeth as in the ordinary file, tungsten carbide grit is permanently imbedded in the surfaces. This file has a very fast action in wood, since it will cut in any direction. It will also cut soft metals but is not recommended for the harder metals, such as iron or steel.

CHAPTER 5

Boring Tools

There are several kinds of boring tools, each class adapted to meet special working conditions, such as:

1. Punching.
2. Boring.
3. Drilling.
4. Countersinking.
5. Enlarging.

The various kinds of tools used for these operations are respectively: brad awls, gimlets and augers, drills, hollow augers and spur pointers, countersinks, and reamers. If these tools are not equipped with a permanent handle but are designed to be used in some type of holder, such as a brace, they are called *bits*.

Punches—There are several types of punches, differing in size and application, as shown in Fig. 1. A center punch is used to indent a point already marked with scriber or pencil, prior to boring. The spacing punch shown at the extreme right in Fig. 1 is used to facilitate exact spacing between holes. This type of punch is often very useful where a large number of small holes must be placed at regular intervals.

Brad Awls—An awl is a pointed tool used for piercing small holes for screws and nails. The blade is shaped and pointed to suit the conditions of use. Brad awls have an edge like a screwdriver. To avoid splitting the wood start the awl with its edge across the grain, rotating it slightly as it is pressed down. Do not let the edge come parallel to the grain.

Gimlets—These are for boring small holes by hand pressure, although the auger-bit type of gimlet can be used in a brace for

heavier and quicker boring than the gimlet which is equipped with a handle.

Common Types of Wood Bits—There are several types or styles of wood bits suitable for various types of boring. In this connection, it should be noted that a distinction is sometimes made

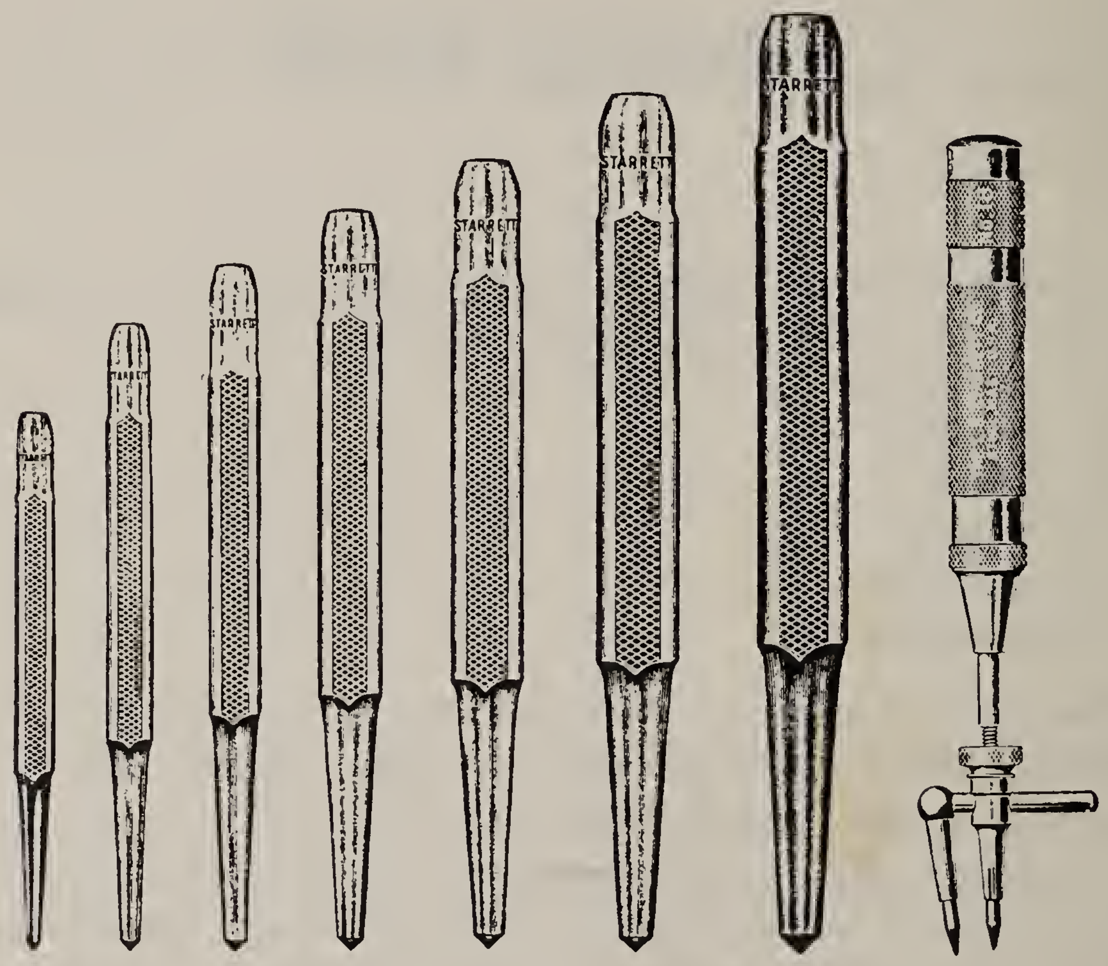


Fig. 1. Various-sized center punches used to locate holes for boring or drilling. The example at the extreme right is called a spacing punch.

in the cutting operation, in that a hole made in wood is termed *boring* while a similar operation in metal is termed *drilling.* In general practice, however, the term drilling applies to operations in both wood and metal alike.

Auger Bits—These are used for boring holes from ¼ up to two inches. Bits are marked for size by a single number which is the numerator of a fraction stating the diameter of the bit. Auger bits and Forstner bits are listed by 16ths of an inch; thus, for example, No. 8 stands for 8/16 in. or ½ inch. Some auger bits have the size, for example ½, stamped on the shank. Twist bits for wood are usually marked in the same way, but by 32nds; that

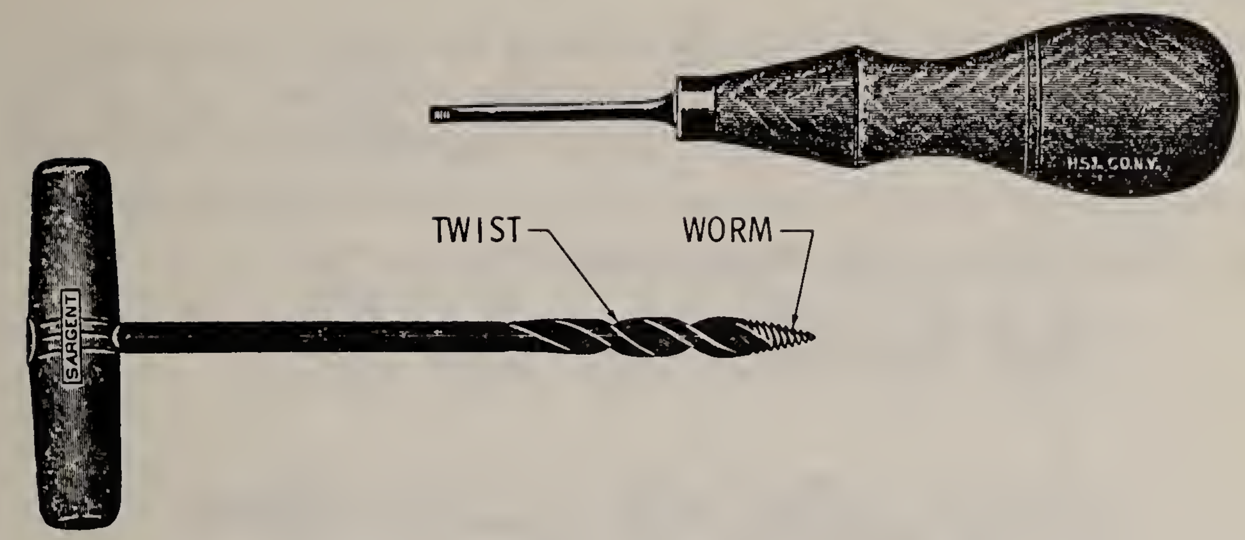


Fig. 2. Typical brad awl and gimlet. Brad awls and gimlets are used to make small holes in wood, thus making it easier to start nails and screws. In using the gimlet the handle is grasped in the right hand and pressed into the wood by the palm (in starting), the shaft of the tool projecting between the first and second fingers. It is driven into the wood by a series of half turns, being released and regrasped at each half turn.

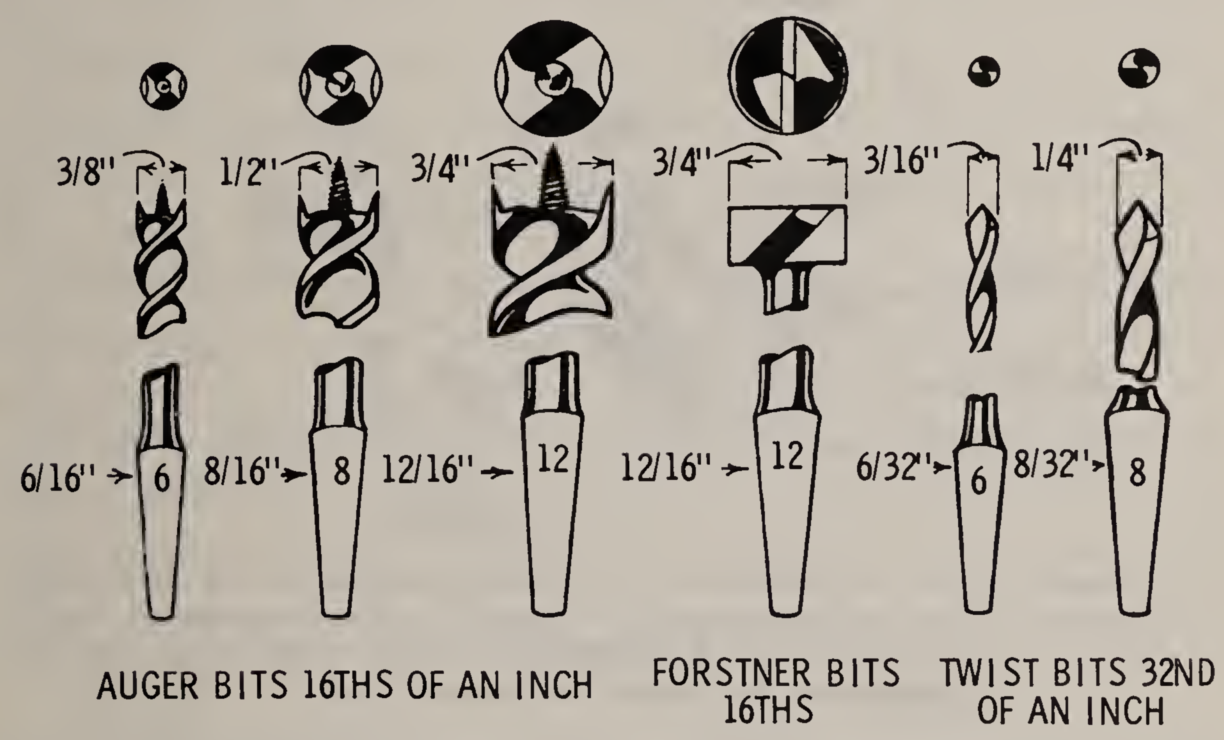


Fig. 3. Typical auger, Forstner, and twist bits, and methods of marking for size.

is, No. 8 stands for 8/32 in. or ¼ inch. Fig. 5 shows two common styles of wood bits. One has a screw point, the other a brad or diamond point. It should also be noted one style shows a solid center with a single spiral running around it, while the other style is a double-spiral twist bit.

Fig. 6 shows a hollow-spiral bit, which has a screw point and only one cutting edge, the function of its hollow center being to

permit the passage of chips. Because of its construction, this bit cuts very fast and is used exclusively for deep holes. A typical expansive bit is shown in Fig. 7. The expansive bit is so called because it may be set for various diameter holes within its capacity, thus taking the place of many large bits.

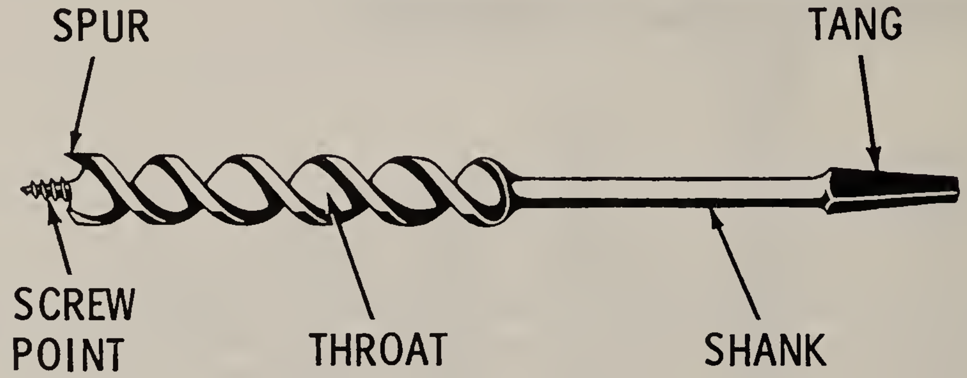


Fig. 4. Typical auger bit with nomenclature.

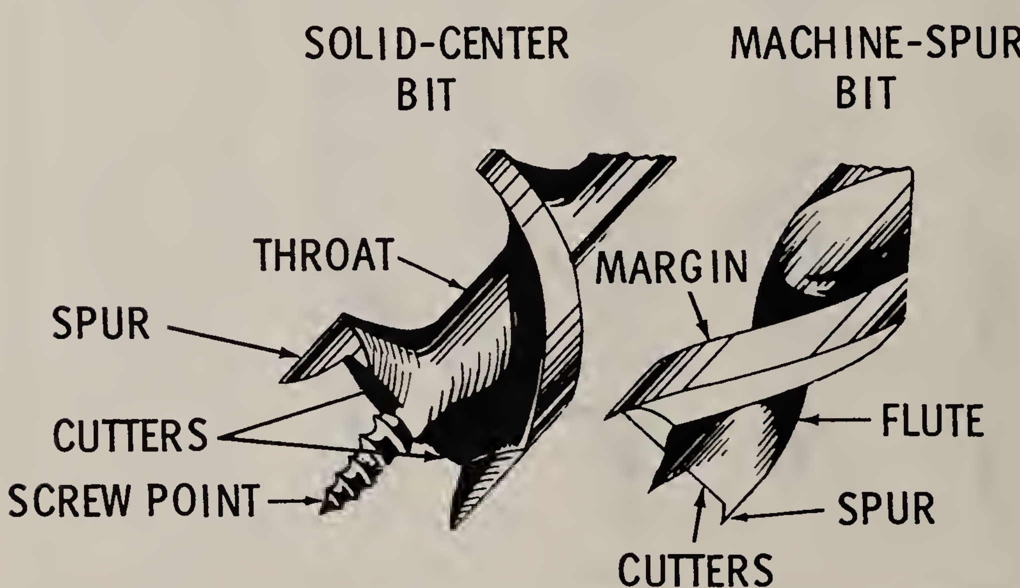


Fig. 5. Common types of wood bits. The cutting edges of the bits shown are very similar. The opening between the spiral is called the throat, but in some styles of double-twist bits it is called the "flute". Both terms are used alternately and mean the same thing.

Another excellent bit for large holes is the multispur type shown in Fig. 8A, but although this drill is relatively low in price, it does not lend itself to boring holes of various diameters.

A double-spur bit in a twist-drill pattern is shown in Fig. 8B. This is one of the fastest and cleanest cutting types of wood bits. The flat center bit with only one cutting edge, as shown in Fig. 8C, is used for drilling of large shallow holes. When drilling countersunk holes, a bit such as illustrated in Fig. 8D may be used. A drill of this type is often used in production work where

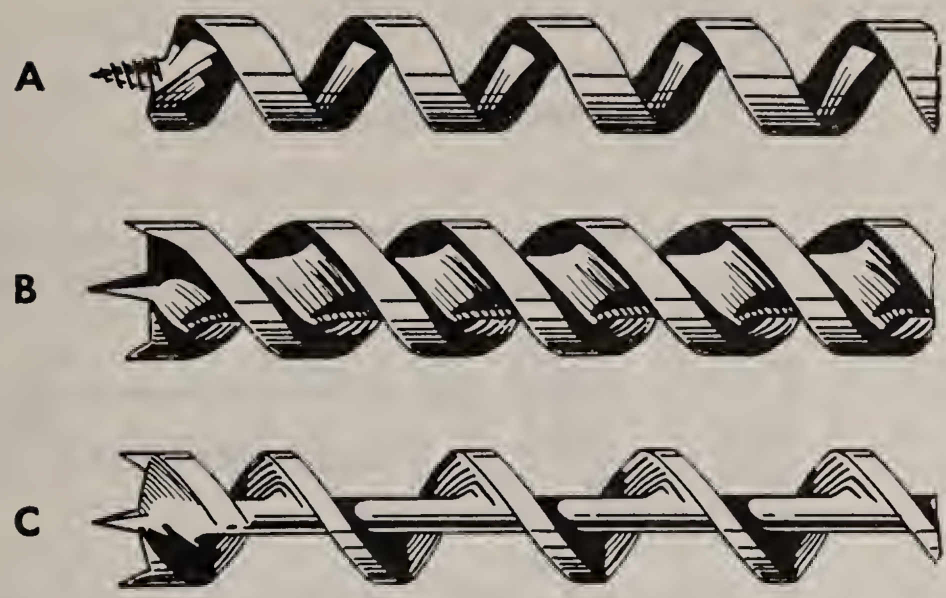


Fig. 6. Typical auger-bit styles. The auger bits shown represent (A) hollow-spiral bit (single twist); (B) double-spur bit (fluted) and (C) double-spur bit (solid center) respectively.

the cutting of both hole and countersink can be performed in a single operation.

Depth Gauge—When necessary to drill holes of exact depth, an adjustable bit gauge such as shown in Fig. 9 may be used. This is a simple clamping device which can be attached to any standard bit by means of wing nuts as illustrated.

Other Bit Types—Among other bit types frequently found in workshops are router bits, end cutters for cutting rosettes, and a variety of other patterns. Fig. 10 shows several bit styles.

Plug Cutters—These can be obtained in sizes from ⅜ inch to one inch by sixteenths of an inch. With cutters of this type, cross-grained plugs up to one inch thick can be cleared through

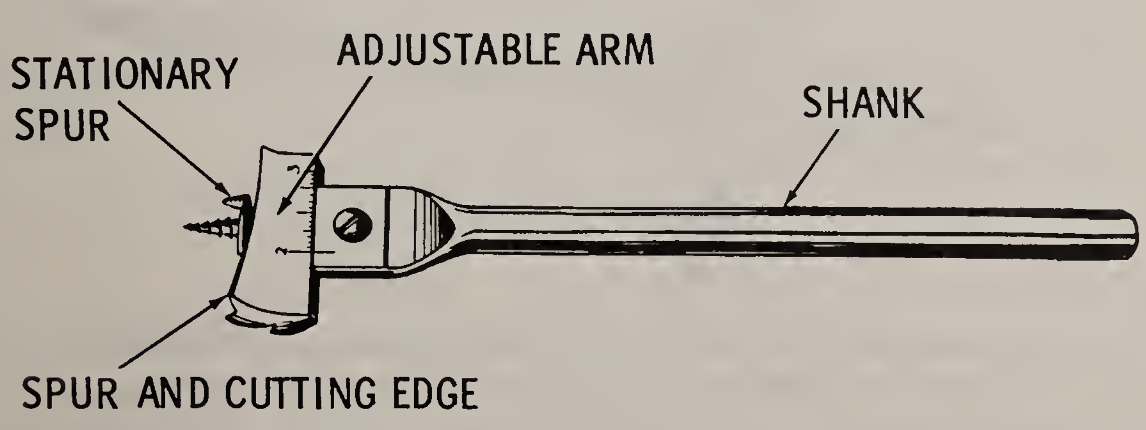


Fig. 7. Typical expansive auger bit with adjusting screw. The expansive bit takes the place of many larger bits. The cutter may be adjusted for various size holes. Moving the cutter adjusting screw one complete turn enlarges or reduces the hole ⅛ in. For correct setting, test for size on a piece of waste wood. For boring through it is advisable to clamp a piece of waste wood on the back of the work to prevent splitting.

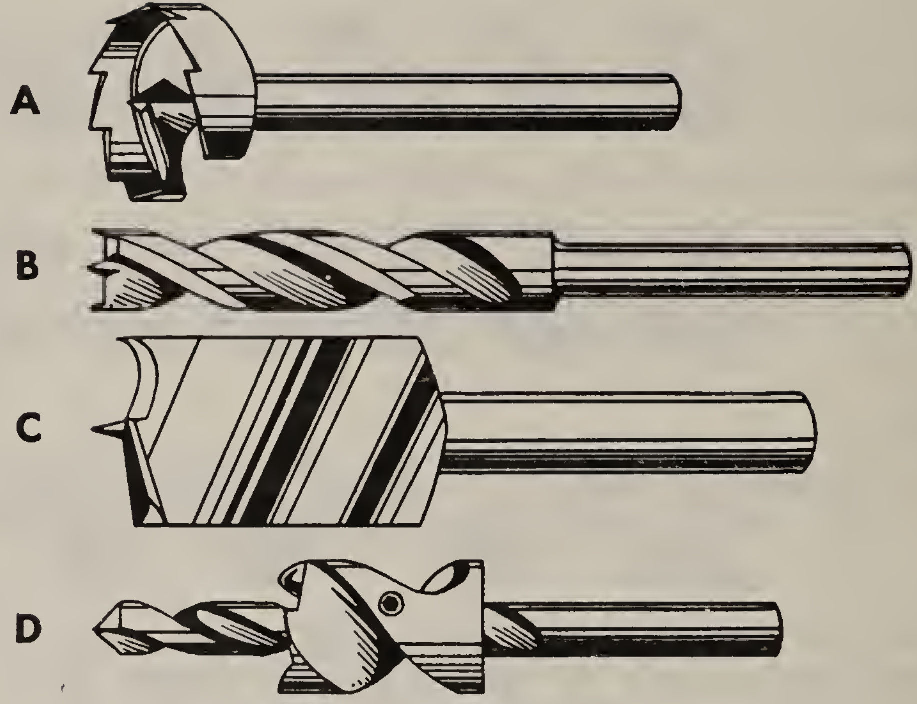


Fig. 8. Various special wood bit styles. The bits illustrated represent, (A) a multispur bit; (B) a double-spur bit; (C) a center bit; and (D) counter-sink bit respectively. Bits not equipped with feed-screw points are usually machine fed, that is, they are for use in the drill press, whereas, bits equipped with screw points are usually for use in the bit brace.

the center opening, while the full length of the cutter will make dowels up to two inches in length.

Use of Twist Drills for Wood—In addition to various types of bits for wood, a woodworker should also possess a set of twist drills, because the common styles of twist drill used for metalwork can be used successfully in wood as well. Twist drills are for either wood or metal, but never use auger bits on metal.

Fig. 9. Depth gauge. An adjustable bit gauge of the type illustrated may be used to regulate the depth of holes to be bored.

As noted in Fig. 11, a twist drill differs from the common wood bit in that it has no screw and a less acute angle of the lip, hence there is no tendency to split the wood that is, the tool does not pull itself in by a taper screw but enters by external pressure. If a

twist drill is used exclusively for woodwork, the point angle should be ground to about 40 degrees instead of the 59-degree angle used for metalwork.

Countersinks—Sometimes it is necessary to make a conical enlargement of a hole at the surface of the wood. This is performed

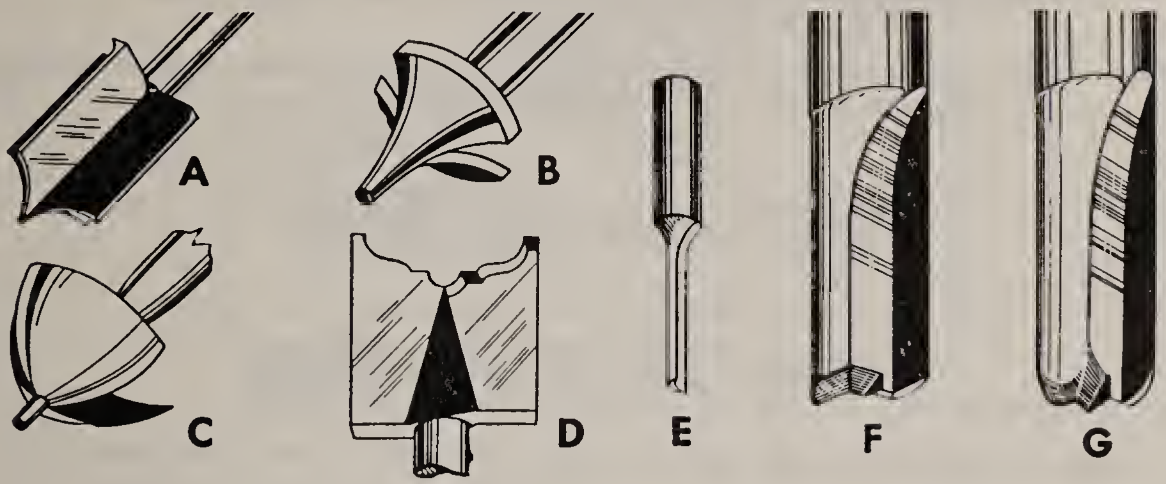


Fig. 10. Special bit styles. In the figures A, B, and C represent end cutters, useful for rounding over and general shaping operations on small work which will not permit the swing of a regular cutter; D, shows a rosette cutter available in a wide variety of different patterns; E, F, and G, are router bits of various sizes in single- and double-flute patterns.

by a tool called a *countersink*. Some types may be used in a hand brace and some types are adapted for the drill press, as conditions require.

Reamers—A reamer is a long tapered tool for enlarging holes, and while used chiefly by machinists, there are frequent occasions in woodworking when a reamer may be employed advantageously.

Hand Drills, Breast Drills and Braces—The hand drill, breast drill, and brace, Fig. 13, are the common hand tools for holding and turning drills. The hand drill is used for rapid drilling of small holes in both wood and metal. Holes in wood should be started with an awl to help center and locate the drill, whereas holes in metal should be center-punched.

The breast drill is similar to the hand drill in construction but is equipped with a breastplate to facilitate the application of additional pressure to the drill when necessary. The brace differs from the hand and breast drill mainly in that here the turning movement is applied directly to the bit by means of the handle swing, whereas the hand and breast drills are equipped with a gear and pinion arrangement for turning the drill.

Boring Tools

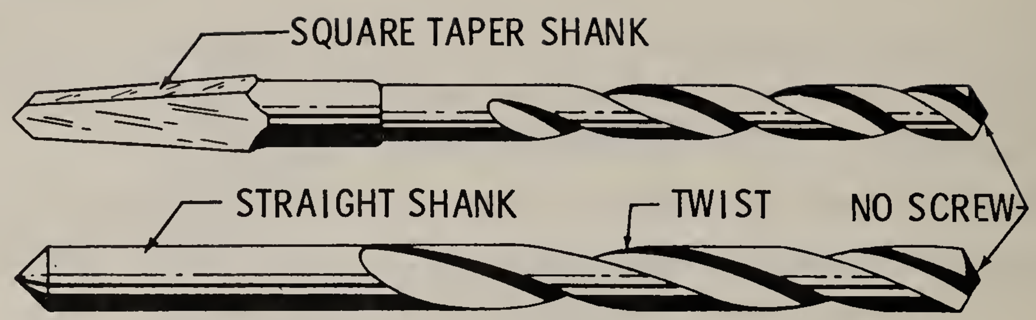


Fig. 11. Typical bit stock twist drill for use with a brace and a straight-shank twist drill for use in the drill press.

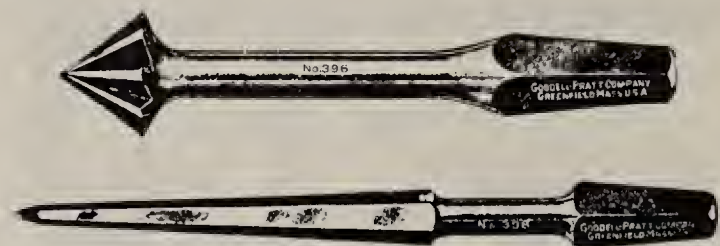


Fig. 12. Typical rose countersink and octagonal-type reamer.

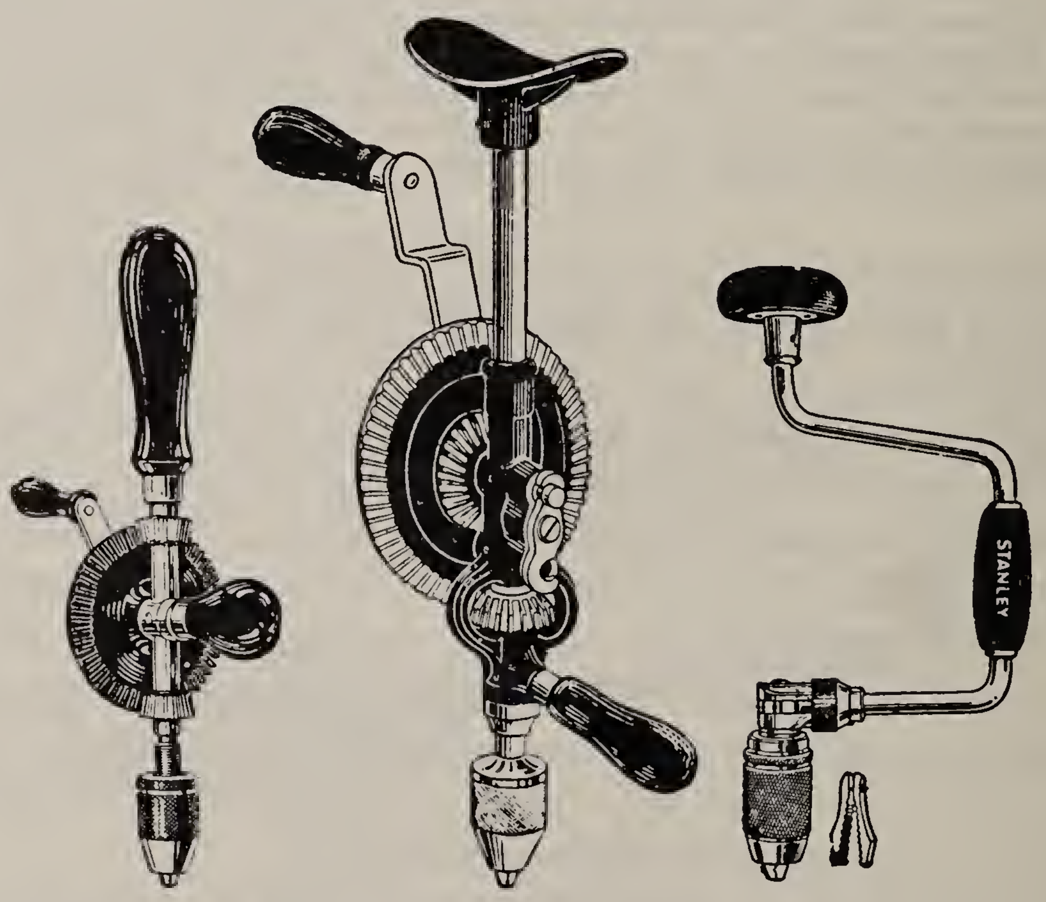


Fig. 13. Hand drill, breast drill, and bit brace respectively.

How to Use Boring Tools—Satisfactory results in the use of boring tools are obtained by practice and the use of good tools, each suitable for the particular job assigned to it. The work should be properly laid out and the hole clearly marked. To bore a vertical hole, hold the brace and bit perpendicular to the surface of

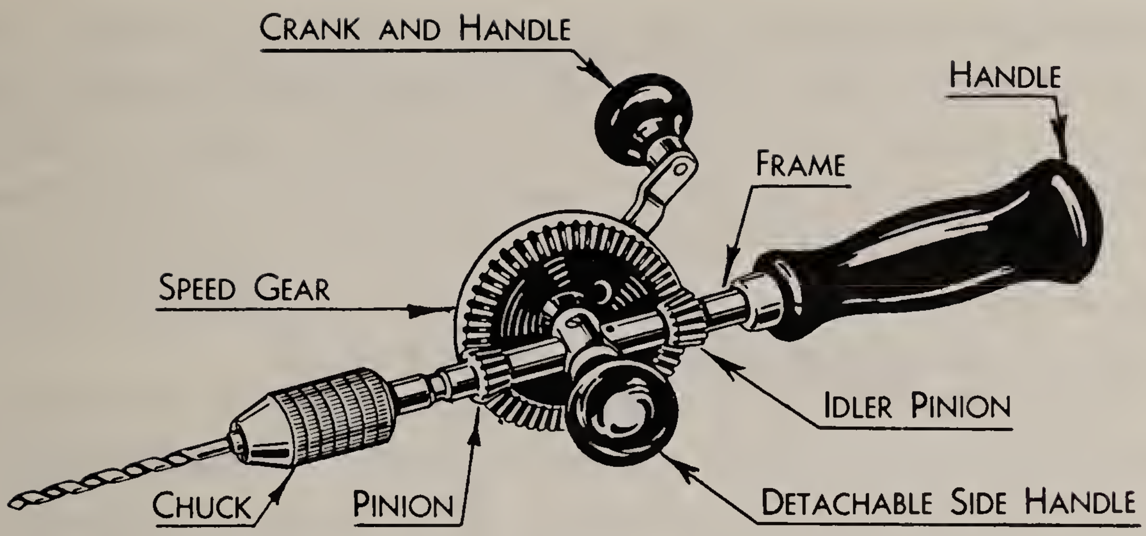


Fig. 14. Hand drill with identification of parts.

the work. Compare the direction of the bit to the nearest straightedge or to sides of the vise. A try square may also be held near the bit to ascertain the true vertical.

To bore a horizontal hole (Fig. 16), hold the head of the brace cupped in the left hand against the stomach, with the thumb and forefinger around the quill. To bore through without splintering the second face, stop when the screw point is through and finish from the second face. When boring through with an expansive bit it is best to clamp a piece of scrap wood to the second face and bore straight through.

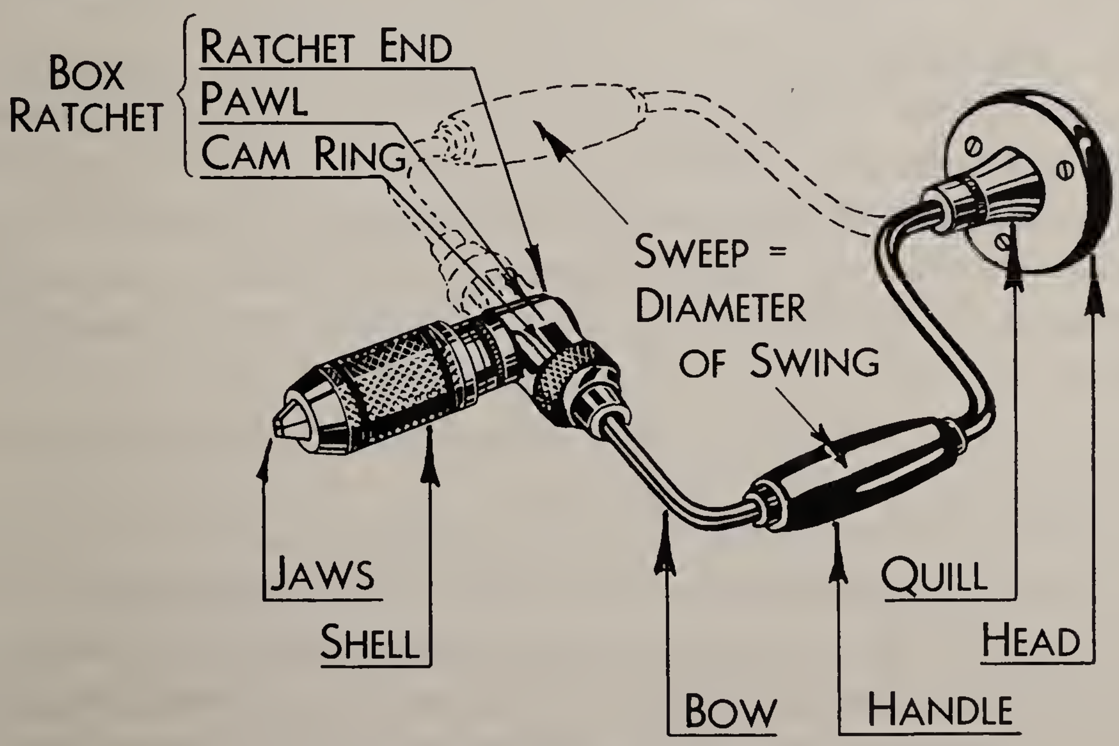


Fig. 15. Hand brace with identification of parts.

Boring Tools

Sometimes restricted working quarters make it necessary to use a *ratchet brace.* The ratchet brace is indispensable when boring a hole in a corner or when an object prevents making a full turn with the handle. To operate the ratchet turn the cam ring. Turning the cam ring to the right will allow the bit to turn right and give ratchet action when the handle is turned left. Turning the cam ring to the left will reverse the action.

Boring Holes with the Drill Press—Here, as in boring holes with hand tools, a certain amount of practice is usually required to bore holes correctly and efficiently. The movable drill press table should be located so that the bit will pass through the table opening after the hole has been drilled. The drill is projected into the work by pulling on the feed lever.

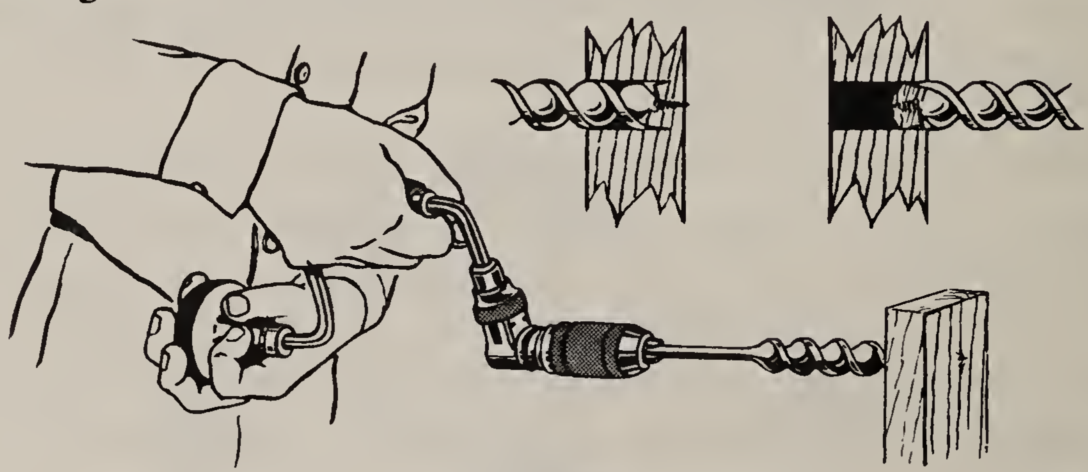


Fig. 16. Method of boring holes horizontally to prevent splitting.

The feed should not be excessive and should be slowed down when the operator judges that the drill is nearly through. Excessive feed at this point will splinter the underside of the board around the hole, or may break the bit when drilling metal. Because it is hard to determine when the hole is almost through, most operators prefer to use a wood block under the work when drilling on the drill press.

For exacting work, the same procedure may be followed with the drill press as when using hand tools—that is, to reverse the work and finish the boring from the opposite side of the work. In this connection, it should be noted that while threaded-feed-screw type auger bits are preferred when boring with hand tools, spur-type auger bits should never be used in the drill press. Straight-shank drills should not be used in the bit brace and auger bits should never be used in the drill press.

CHAPTER 6

Fastening Tools

The term *fastening tools* means those hand tools which are used in the operation of securing or joining various parts of wood or other materials together with nails, tacks, screws, bolts, etc. The tools employed comprise the various hammers, screwdrivers and wrenches.

Hammers—The hammer is a very simple striking tool and is made in numerous sizes and shapes to meet the various conditions of service. All hammers worthy of the name are made of the best steel, carefully forged, hardened, and tempered. Depending upon their use, hammers may be divided into several groups or classifications, such as:

1. Nail or claw.
2. Ball peen.
3. Cross and straight peen.
4. Tinner's and riveting.
5. Soft face.

Hammer handles are usually of hickory with transparent lacquer finish, and are carefully balanced with the head, thus delivering a maximum of power in every swing. All hammers, regardless of their classification, are sized according to the weight of the head without the handle, such as 10 oz., 13 oz., 16 oz., 20 oz., etc.

As the name implies, nail hammers are used primarily for nailing, being provided with differently curved claws to aid in the removal or drawing of nails. The shape of the face may be either flat or rounded (bell-faced). The bell-face pattern differs from the flat-face pattern mainly in that the face of the former is slightly rounded, rendering less likely the possibility of the hammerhead marring the wood.

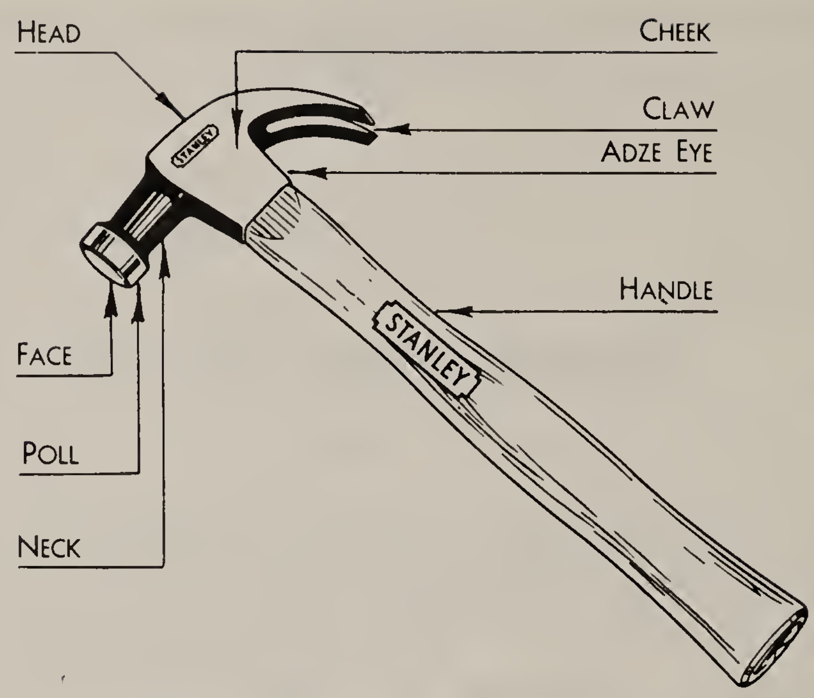


Fig. 1. Bell-faced nail hammer.

The ball peen* hammer (Fig. 3) is the mechanic's all-around tool and is used in various applications where medium and heavy blows are required, such as in blacksmithing, riveting, shaping, etc. Because of their frequent use in heavy-duty work, ball-peen hammers are made in sizes up to 40 ounces or 2½ pounds.

Cross- and straight-peen hammers differ from the ball-peen type mainly in that the peen is wedge shaped instead of hemispherical, the wedges being arranged either perpendicular or parallel to the handle as illustrated in Fig. 4. Tinner's riveting hammers, as the name implies, are used for forming of rivets in sheet metal and similar work and have a slightly rounded square face and cross-peen head as shown in Fig. 5.

A soft-face hammer is shown in Fig. 6. A feature of this tool is renewable tips which are clamped in the head of the hammer. The tips may be of rawhide, babbit, copper or plastic that will not mar finely finished surfaces. This tool is used in forming of soft metals, assembly work, home workshops and in automotive repairs.

How to Use a Hammer—When using a hammer for driving nails, the handle should be grasped at a short distance from the end and a few sharp blows rather than many light ones given.

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* By definition the word "peen" means the end of a hammerhead opposite the face when adapted for striking, usually shaped for indenting, as when pointed, conical, hemispherical or wedge shaped.

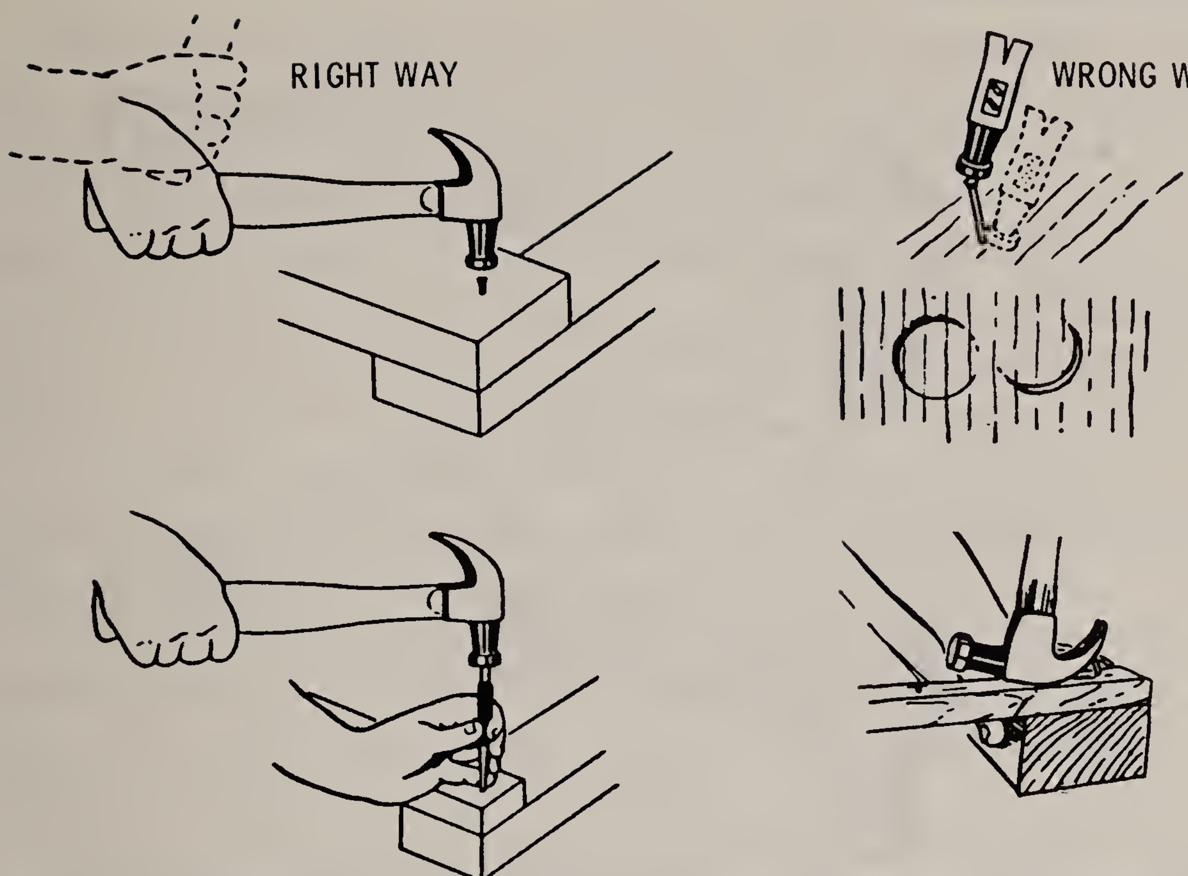


Fig. 2. Illustrating right and wrong ways to drive a nail. Strike the nail squarely on the head as shown. This means that the handle should be horizontal when the hammer hits the vertical nail—not inclined. Figure 2 also shows a method of setting the nail below the surface of the wood and the use of claws when pulling nails.

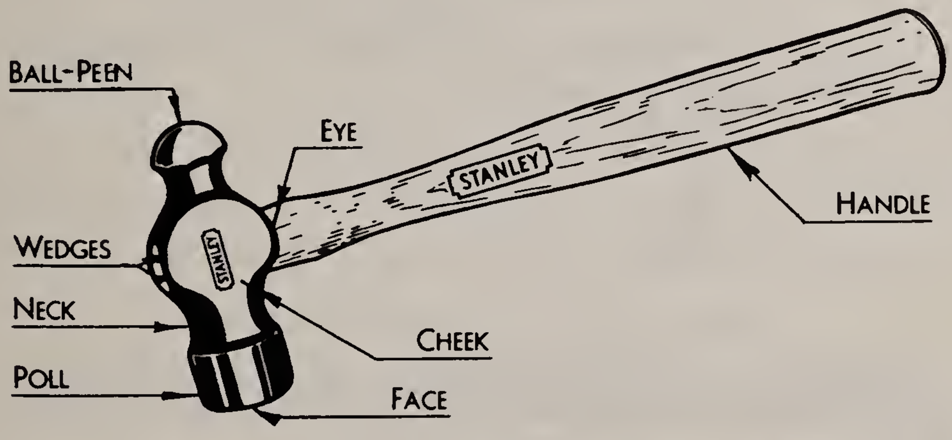


Fig. 3. The ball-peen hammer. Ball-peen hammers are made with hardened steel faces and fitted with a handle of hickory or other hardwood.

Keep the hand and wrist level with the nail head so that the hammer will hit the nail squarely on the head instead of at an angle. Failure to do this is the reason for the difficulty so often experienced in driving nails straight. To strike light blows, as in marking for holes with a prick punch and similar work, grasp the handle nearer the head and swing with a slight motion at the elbow but a larger motion at the wrist.

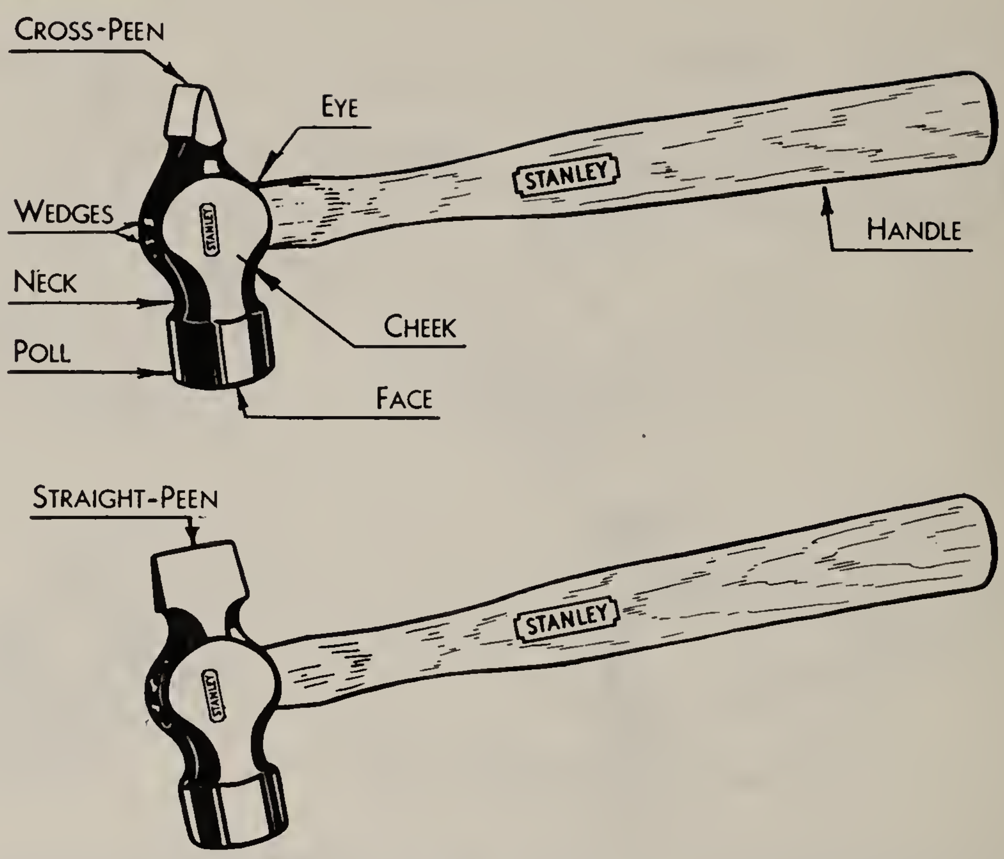


Fig. 4. Cross- and straight-peen hammers respectively.

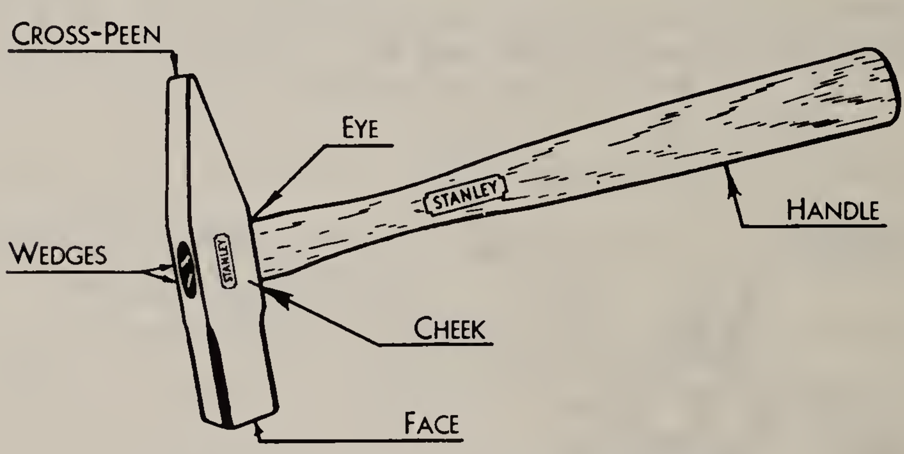


Fig. 5. Tinner's riveting hammer.

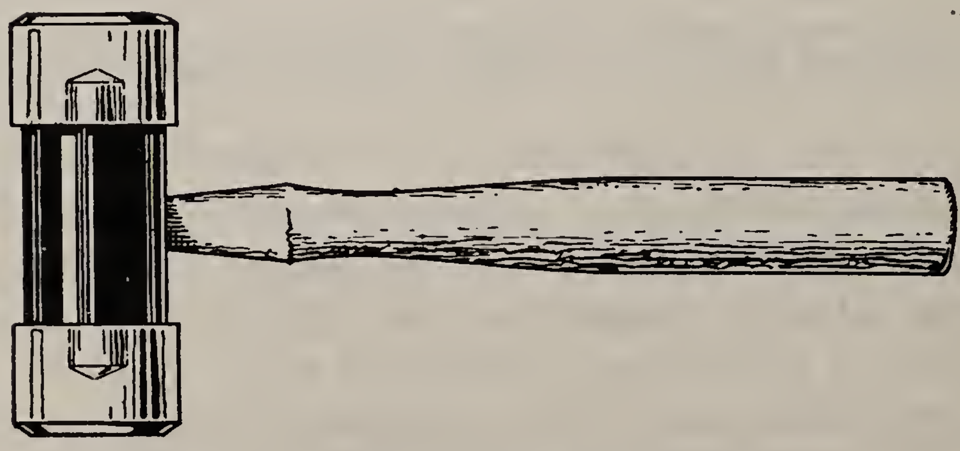


Fig. 6. Typical soft-face hammer.

The hammer handle should always be tight in the head. Never work with a hammer having a loose head, because of the danger of the head flying off and causing an injury. After the handle is inserted in the head, a steel wedge is driven into the end of the handle. This expands the handle in the opposite taper in the eye and thus the handle is wedged in both directions. If the wedge becomes loose, it should be driven in again to tighten the handle. Do not use the end of the hammer handle for bumping purposes, or for prying, because this will split or break it. Always keep the hammer clean and free from grease and dirt. A slight coating of light oil will prevent rust from forming on the metal head.

Screws—Screws are used in preference to nails in numerous working projects, because of (1) their greater holding power; (2) neater appearance; (3) less chance of injuring the material, and (4) ease of removal in case of repairs.

All screws that are turned by a screwdriver are called "wood" screws as distinguished from those having square or hexagon heads turned by a wrench. Common wood screws are regularly made of soft steel, aluminum, and brass, with three styles of head: namely, *flat*, *round* and *oval* as shown in Fig. 7. The use of oval heads is comparatively limited, with flat heads constituting fully four-fifths of the total demand and round heads three-fourths of the remainder.

Sizes of wood screws are designated by length in inches and fractions thereof, and by diameters in numbers of the American screw gauge. The length of the flat-head wood screw is the overall length, but the length of round-, oval- and fillister-head screws is

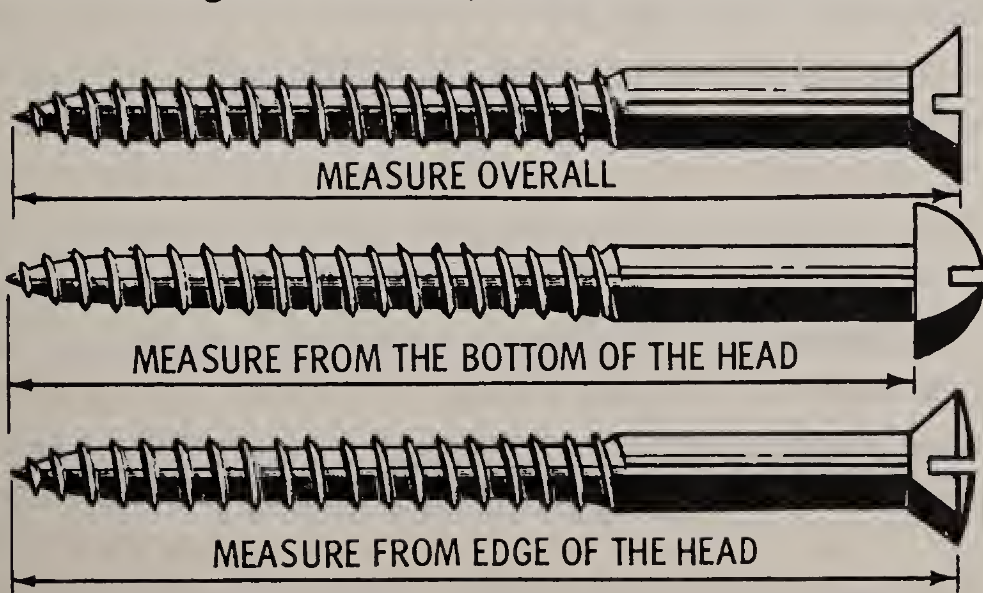
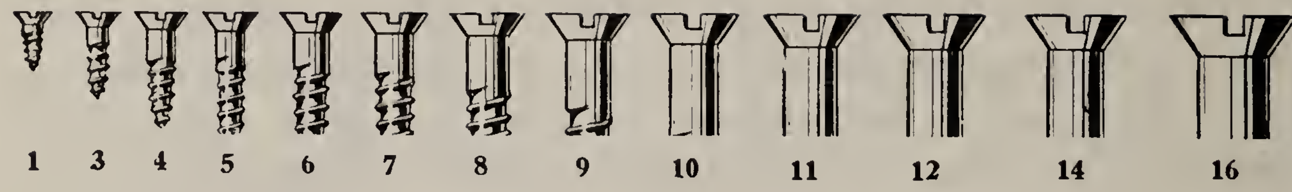


Fig. 7. Common flat-head, round-head and oval-head screws respectively.



LENGTH	GAUGE NUMBERS																
¼ INCH	0	1	2	3													
⅜ INCH			2	3	4	5	6	7									
½ INCH			2	3	4	5	6	7	8								
⅝ INCH				3	4	5	6	7	8	9	10						
¾ INCH					4	5	6	7	8	9	10	11					
⅞ INCH							6	7	8	9	10	11	12				
1 INCH							6	7	8	9	10	11	12	14			
1¼ INCH								7	8	9	10	11	12	14	16		
1½ INCH							6	7	8	9	10	11	12	14	16	18	
1¾ INCH									8	9	10	11	12	14	16	18	20	
2 INCH									8	9	10	11	12	14	16	18	20	
2¼ INCH										9	10	11	12	14	16	18	20	
2½ INCH													12	14	16	18	20	
2¾ INCH														14	16	18	20	
3 INCH															16	18	20	
3½ INCH																18	20	24
4 INCH																18	20	24

Fig. 8. Table giving lengths and diameters of common wood screws.

measured from the point to the underside of the head, as noted in Fig. 7. Wood screws are regularly made in sizes ranging from ¼ inch to 4 inches in length and from gauge No. 0 to No. 24, as noted in Fig. 8. In ordering screws, specify (1) length, (2) gauge number, (3) type of head (flat, round or oval), (4) material (steel, brass, bronze, etc.), and (5) finish (bright steel, blued, cadmium, nickel or chromium plated). Sizes of bits or drills to bore holes for wood screws are given in Fig. 9.

Nails—While wood screws are used in fastening together various articles around the home, nails have had exclusive use for many generations by carpenters as fasteners in the assembly of wooden buildings. Common nails or brads are designated by the term "penny," the origin of which is uncertain. The letter "d" is used to indicate "penny" and serves as a means of determining nail size. Thus, for example, 4d signifies a 4-penny nail, whose length is 1½ inches, and 5d, a 5-penny nail, etc. The lengths corresponding to the more common sizes are 4 penny, 1½ inch; 6 penny, 2 inch; 8 penny, 2½ inch; 10 penny, 3 inch; 20 penny, 4 inch; 60 penny, 6 inches.

Although the penny size of nails or brads to use for a certain project depends upon the thickness of the material and the strength

required, common sense and experience usually provide the best solution to problems of this kind. In addition, it is of course poor economy to use a 10-penny nail where a 6-penny nail would do.

To determine the length in inches of common nails or brads for a given penny size, up to and including 10d, divide the penny size by 4 and add ½. For example, a 6d nail measures 2 inches—that is, 6/4 + ½ = 2. The length of an 8d nail may similarly be found as 8/4 + ½ or 2½ inches. Common nails or brads (sometimes termed wire nails or wire brads) are regularly made in sizes from one inch (2d) to six inches (60d) according to the table, Fig. 10. Nails are commonly purchased by the pound, although when larger quantities are required, they are purchased by the keg, which contains 70 lbs.

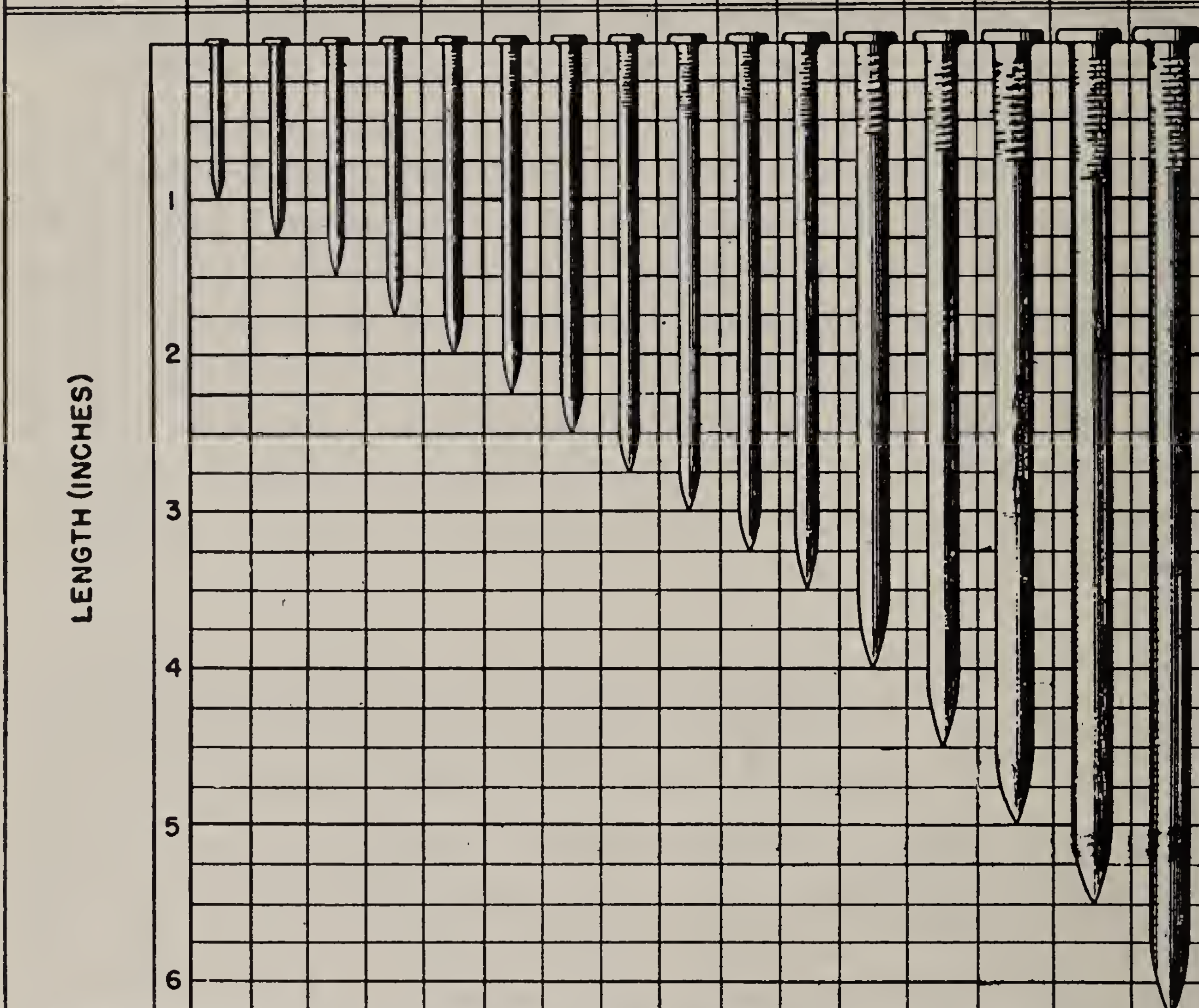
NUMBER OF SCREW		1	2	3	4	5	6	7	8	9	10	12	14	16	18
BODY DIAMETER OF SCREW		.073	.086	.099	.112	.125	.138	.151	.164	.177	.190	.216	.242	.268	.294
		5"/64-	3"/32-	3"/32+	7"/64+	1"/8	9"/64-	5"/32-	11"/64-	11"/64+	3"/16+	7"/32-	15"/64+	17"/64+	19"/64-
FIRST HOLE	TWIST DRILL SIZE	5"/64	3"/32	7"/64	7"/64	1"/8	9"/64	5"/32	11"/64	3"/16	3"/16	7"/32	1"/4	17"/64	19"/64
	AUGER BIT NUMBER							3	3	3	3	4	4	5	5
SECOND HOLE	TWIST DRILL SIZE		1"/16	1"/16	5"/64	5"/64	3"/32	7"/64	7"/64	1"/8	1"/8	9"/64	5"/32	3"/16	13"/64
	AUGER BIT NUMBER												3	3	4

Fig. 9. Table giving sizes of bits or drills to use when boring holes for common wood screws.

The table (Fig. 10) also gives the diameter and approximate number of nails per pound. Thus, for example, if it is estimated that a certain project requires 1,500 8-penny nails, their combined weight would be 1,500/106, or 14.2 lbs. approximately.

Special-Purpose Nails—In addition to the common nail there is a great variety of nails available to meet the needs of all kinds of construction, such as finishing nails, box nails, roofing nails, flooring brads, clinch nails, hinge nails, etc. As a matter of fact, there are well over one hundred varieties of special purpose nails. With respect to material, most nails are made from steel wire. The grade of steel used in known as low-carbon Bessemer or basic open hearth. Brass and copper nails are used extensively for the better class of boat building.

The plain or barbed nail has sufficient holding power, but where extreme holding power is desired as in crating or boxing goods for



Size	2d	3d	4d	5d	6d	7d	8d	9d	10d	12d	16d	20d	30d	40d	50d	60d
Diameter (inches)	.072	.08	.098	.098	.113	.112	.131	.131	.148	.148	.162	.192	.207	.225	.244	.262
Steel wire gage	15	14	12	12	11	11	10	10	9	9	8	6	5	4	3	2
Number per pound	900	615	322	254	200	154	106	85	74	57	46	29	23	17	14	11

Fig. 10. Table giving lengths and diameters of common nails.

shipment, cement-coated nails are used. Coated nails are sometimes used in laying flooring, to prevent springing. Where protection against rust is desired, nails are galvanized.

Screwdrivers—These tools are designed to insert or remove screws. They have, however, been used as a substitute for many other tools. There are several classes of screwdrivers used in the average workshop, such as:

1. Plain.
2. Ratchet.
3. Offset.
4. Phillips.

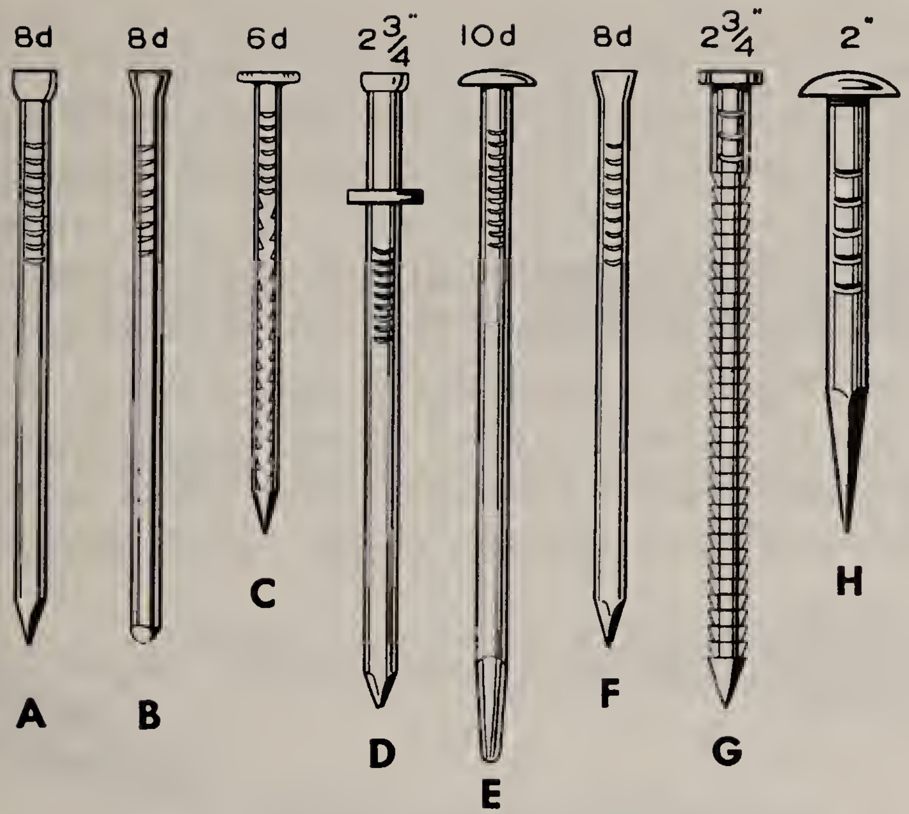


Fig. 11. Various types of special-purpose nails (full size). In the illustration A, represents the finishing nail; B, the flooring brad for hardwood; C, the barbed box nail; D, the duplex-head nail for concrete forms and scaffolding; E, the clinch nail; F, the flooring brad; G, the fetter-ring nail; and H, the hinge nail.

The plain or standard screwdriver (Fig. 12) is very similar to a chisel and differs from the latter chiefly in the working end, which is blunt. There are very few screwdrivers with correctly shaped blade tips. The sides which enter the slot in the screw are usually tapered. This is done so that the end will fit into slots of widely varying sizes.

When using a screwdriver having a tapered blade tip, a force is set up due to the taper which tends to push the end of the tool out of the slot. Accordingly, it is better to have several sizes with

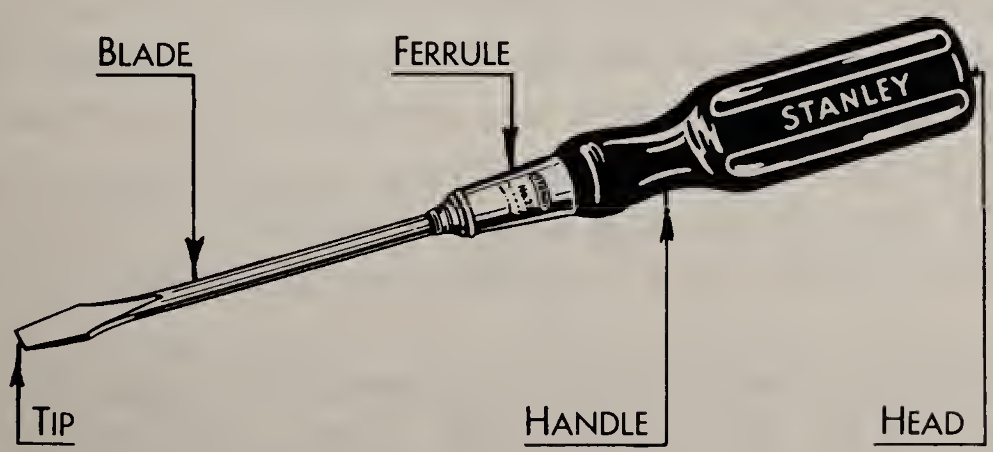


Fig. 12. Plain screwdriver.

properly shaped parallel sides than to depend on one size with tapered sides for all sizes of screws. The ratchet screwdriver resembles an ordinary screwdriver, with the exception of a sliding button on the ferrule. This button is the ratchet shifter and, when placed in its different positions, allows the handle to ratchet to the left or right, or locks the handle and shaft rigidly together.

The spiral-ratchet screwdriver (Fig. 13) consists essentially of a spiral-groove spindle, a chuck sleeve, ratchet shifter, and built-in handle spring. The spindle has two spirals, one right and one left, with corresponding nuts. The screwdriver drives or withdraws screws, according to the position of the ratchet shifter, because

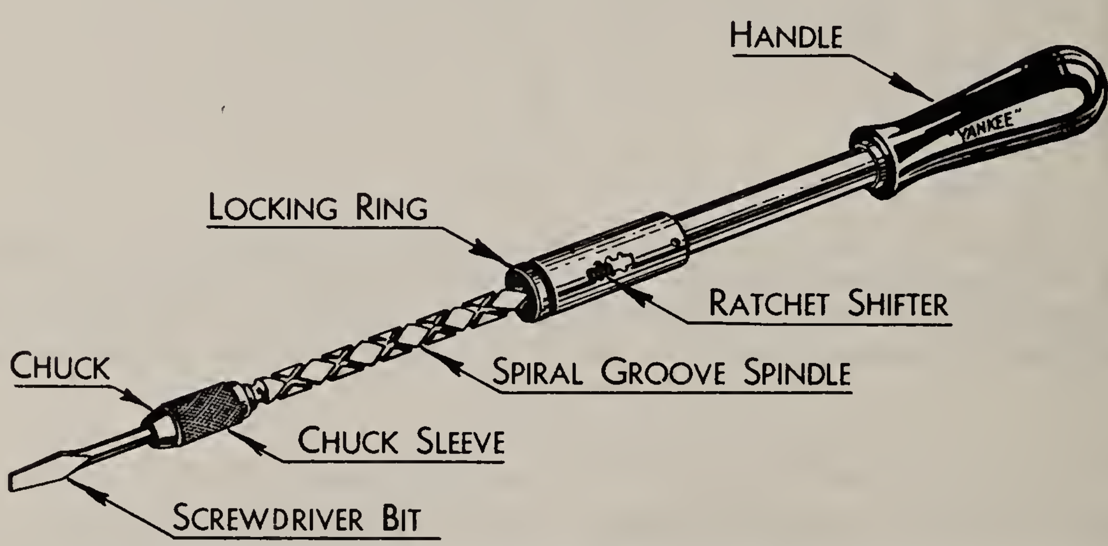


Fig. 13. Yankee spiral-ratchet screwdriver.

pressure on the handle causes the spindle and tip to rotate. The ratchet shifter can also lock the screwdriver into a rigid unit like a conventional screwdriver.

The offset screwdriver (Fig. 14) is a handy tool in tight corners. It has one blade forged in line with the shank or handle and the other blade at right angles to the shank. With such an arrangement, when the swinging space for the screwdriver is limited, the ends can be changed with each turn and thus work the screw into or out of its position. This type of screwdriver is used only when the screw location is such that a plain or spiral-ratchet screwdriver cannot readily be used. The offset screwdriver is also available as a ratchet type.

The Phillips screwdriver (Fig. 14) is made with a specially shaped blade tip that fits Phillips cross-slot screws. The heads of these screws have two slots that cross in the center. This checks the

tendency of some screwdrivers to slide out of the slot on to the finished surface of the work. The Phillips screwdriver will not slip and burr the end of the screw if the proper size is selected.

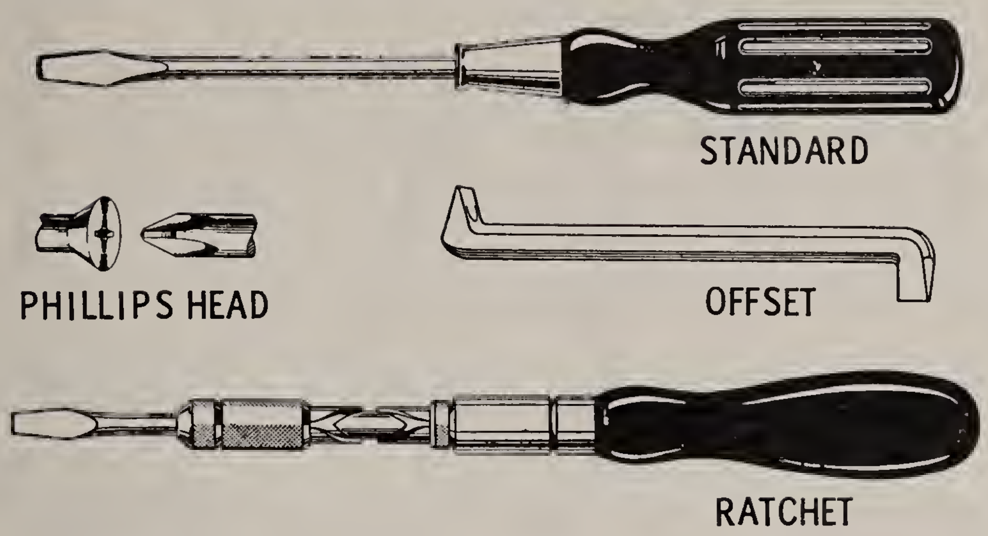


Fig. 14. Typical screwdriver assortment.

How to Use a Screwdriver—When driving a screw, hold the handle of the screwdriver firmly in the palm of the right hand with the thumb and forefinger grasping the handle near the ferrule, as shown in Fig. 15. With the left hand, steady the blade tip and keep it in the slot while renewing the grip on the handle for a new turn. Select a screwdriver of length and blade tip fitted to the work. It is recommended that the longest screwdriver convenient for the work be used because more power can be applied with less danger of the tips slipping out of the screw slot.

Pilot and Shank Holes for Screws—Fastening two pieces of wood together often requires pilot and shank holes to avoid splits in the work or broken screw heads. Small screws can be driven into soft woods without holes, or into small holes made by a brad awl. Bore the holes for large screws with bits or twist drills in two stages as follows:

1. Bore a pilot hole slightly smaller in diameter than the threaded part of the screw to a depth equal to about two-thirds the length of the threaded portion.
2. The second part of the boring procedure consists in boring the shank hole, which should be of slightly larger diameter than that of the screw shank, and of the same depth as the length of the shank.

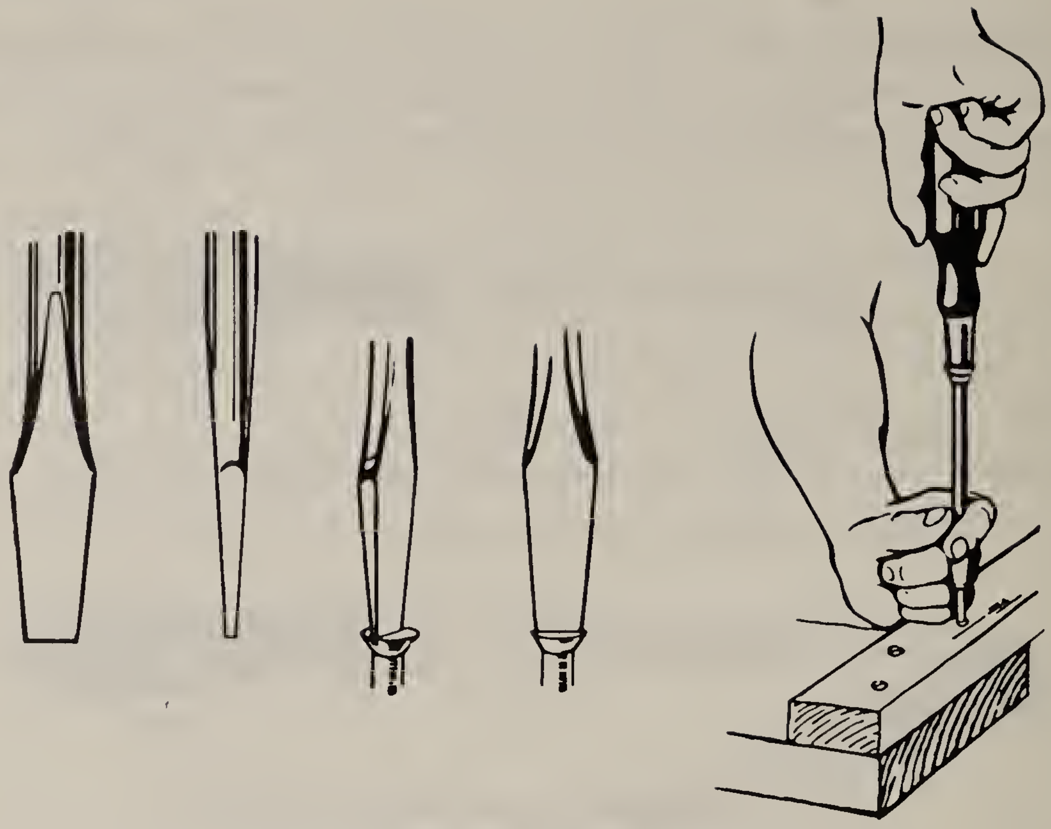


Fig. 15. Screwdriver tip and methods of use.

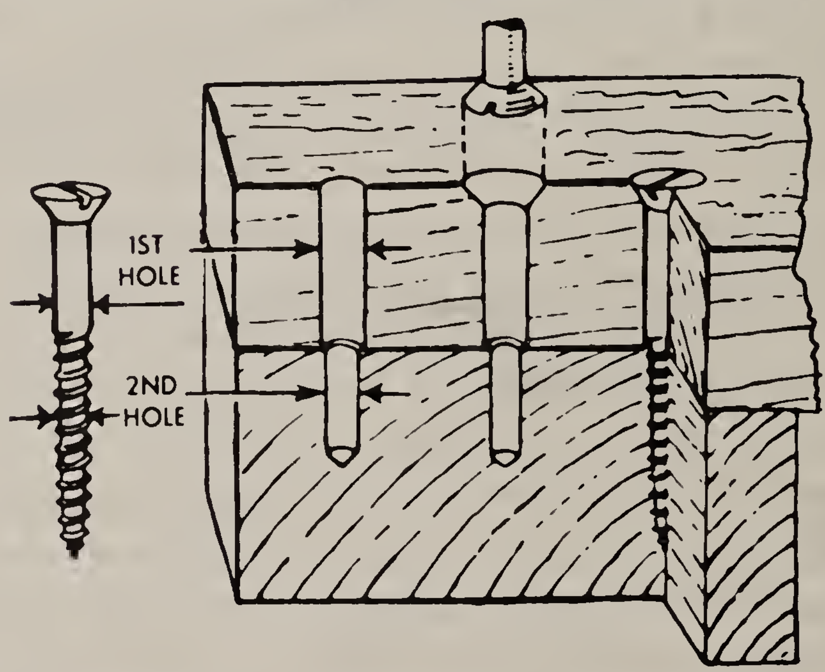


Fig. 16. Method of boring pilot and shank holes for screws.

Countersinking—Countersinking of screw heads is usually required for flat- or oval-head screws. To countersink a screw head, simply use a standard countersink bit of the type used for bit braces, and countersink the clearance hole in the upper piece of the wood to match the diameter of the heads of the screws. When round-head screws or cup washers are used, countersinking is not necessary.

Hardware Fastening—When fastening hardware such as certain kinds of hinges, striking plates, etc., it is often required that the wood be recessed prior to mounting. To fasten hinges or other hardware with screws, proceed as follows:

1. Locate the position of the piece of hardware on the work by scoring a line around it with a suitable tool.
2. Recess the work with a suitable chisel to receive the hardware.
3. Lay the hardware on the work in the recessed area and mark the screw holes.
4. Select screws that will pass easily through the holes in the hardware.
5. Bore pilot holes which are slightly smaller in diameter than the threaded portion of the screws. If the wood is soft, bore the pilot hole only one-half the length of the threaded part of the screw.
6. Drive all the screws in but do not tighten them completely until all are in place.

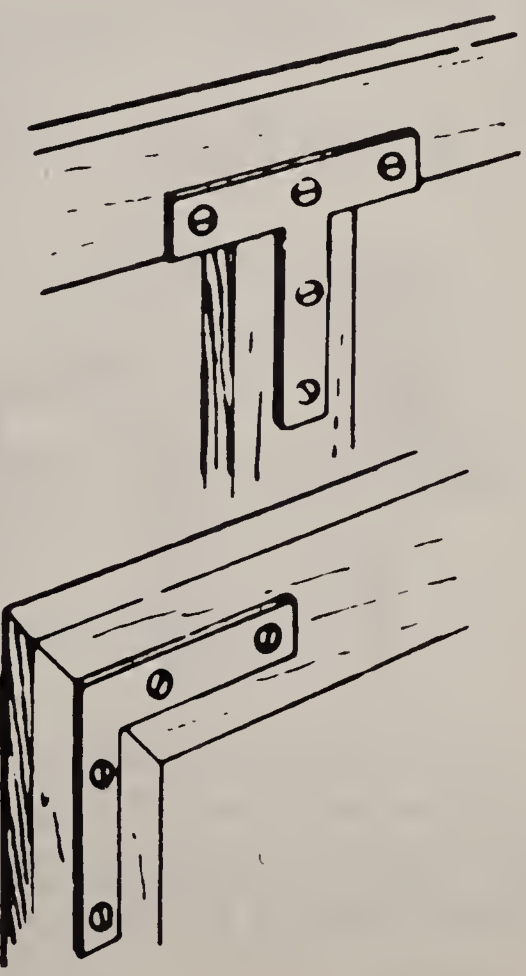


Fig. 17. The use of hardware to provide greater strength in wooden frames of various types.

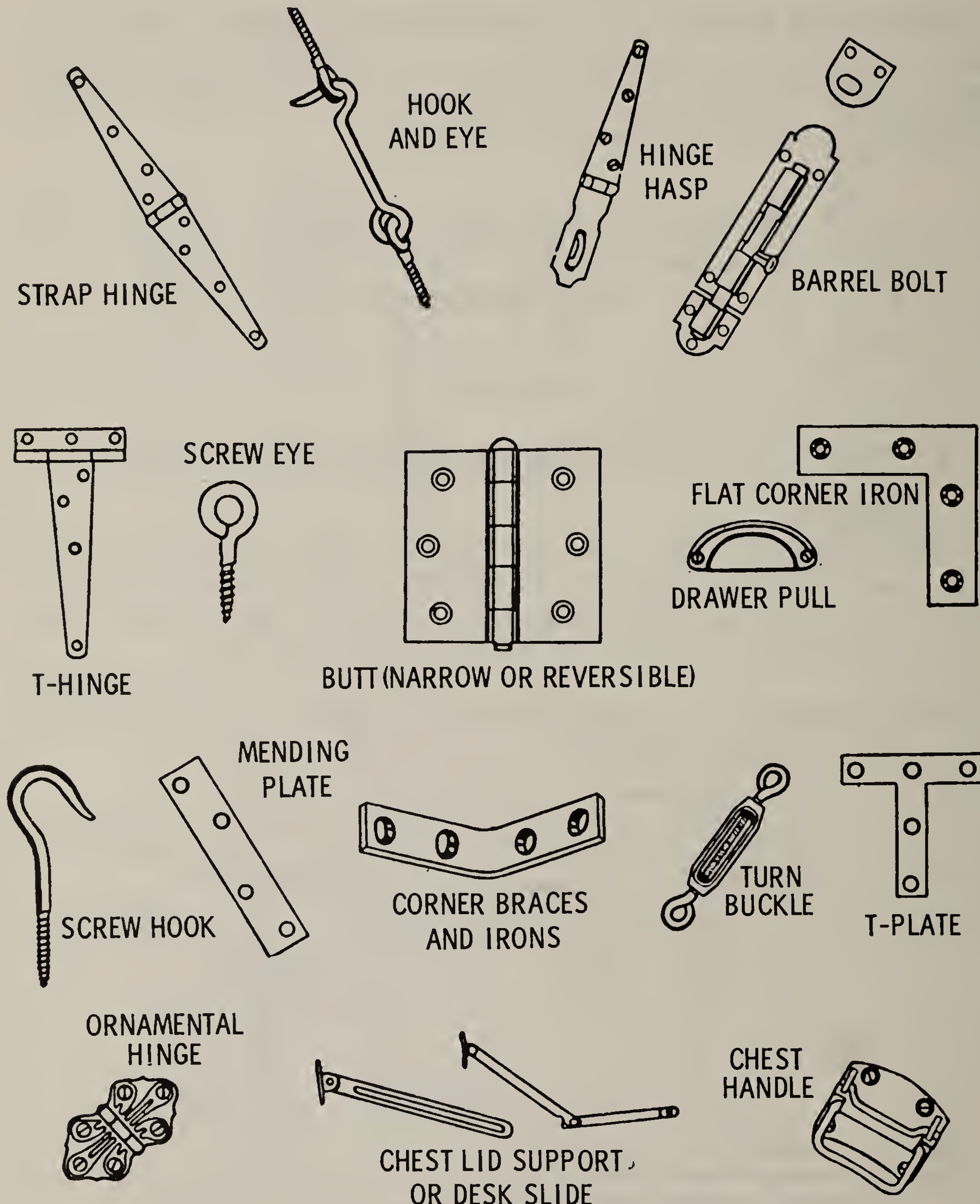


Fig. 18. Frequently used hardware items.

As previously noted, the screws should be of the largest size that will slip easily through the hardware holes. When these holes are countersunk, use oval-head or flat-head screws to fit the countersink. If the holes are not countersunk, round-head screws should be used.

How to Conceal Screws—The general procedure used in the concealment of wood screws is shown in Fig. 19. This consists of boring a suitable hole of the proper depth with an auger bit of the same size as the wooden plug that will be used to conceal the screw head; then bore the proper-sized pilot and clearance holes for the screw.

Next, place the screw and drive it as far as it will go with the screwdriver. Then fill the hole with a suitable wooden plug, preferably of the same material, and with the grain on the end of the plug running in the same direction as the grain on the surface of the work. Plugs should project slightly above the wooden surface when driven home. After the glue has dried, the plug can be cut flush with the surface, using a chisel or a plane to obtain a smooth surface. It should be noted that wooden plugs of various diameters, cut from mahogany, oak, pine, white cedar and cypress, can often be purchased in hardware stores.

Wrenches—The wrench is a tool for tightening or loosening bolts and nuts used in the assembly of numerous articles of wood and other material. The majority of nuts and bolts are hexagonal (six-sided), although other shapes are sometimes encountered. The wrench is designed to grip these nuts or bolt heads and turn them by means of lever action exerted by the handle. Wrenches may be classified according to their design as:

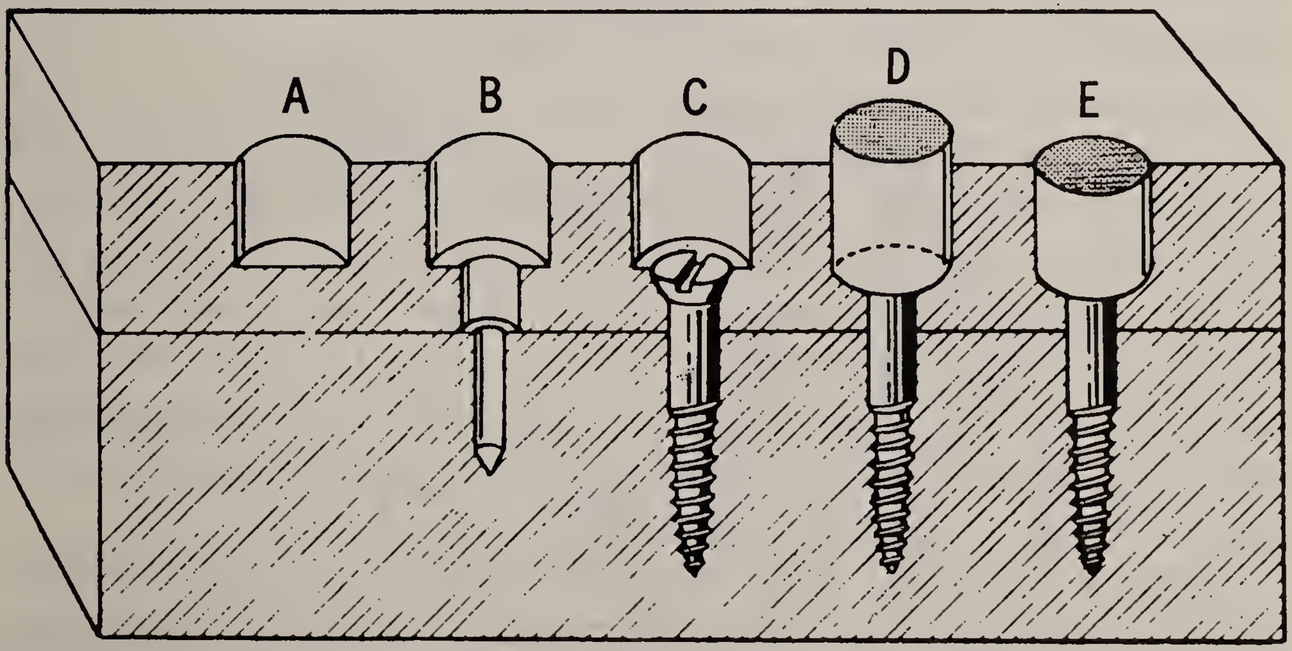


Fig. 19. Step-by-step method of concealing screw heads by means of wooden plugs. A, bore hole to fit wood plug; B, bore pilot and shank holes for screws; C, drive screw in place; D, drive in glued plug to project slightly above work surface; E, after glue has dried, cut plug to surface height, then finish by plane.

Fastening Tools

1. Open end.
2. Adjustable.
3. Monkey.
4. Box end.
5. Combination.
6. Socket, etc.

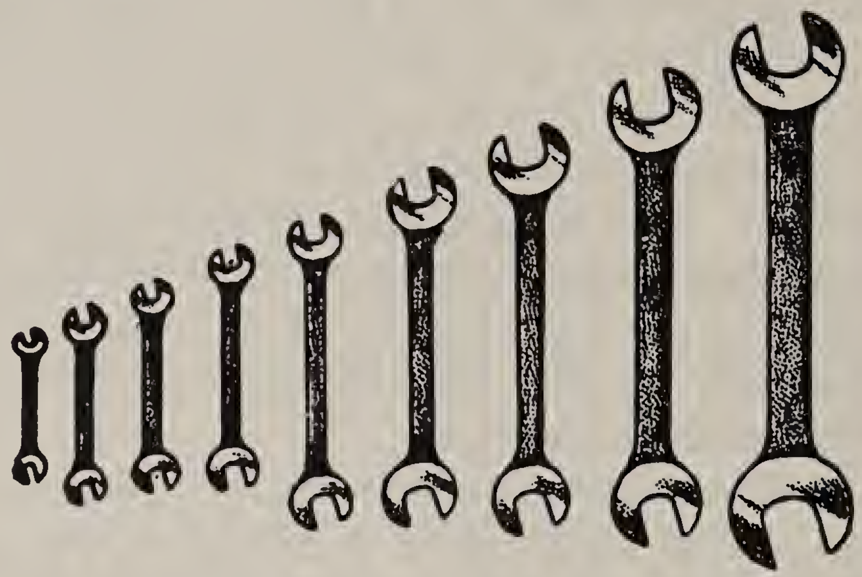


Fig. 20. Typical set of open-end wrenches.

Open-end wrenches are of the solid nonadjustable type with openings in each end. These are customarily made in "sets," with the average set containing about ten wrenches, with openings that range from 5/16 inch to one inch in width.

Adjustable wrenches are shaped somewhat similarly to open-end wrenches, the difference being that one jaw is adjustable as noted in Fig. 21. The angle of the opening to the handle on an adjustable wrench is 22½ degrees. A spiral worm adjustment in the handle permits the width of the jaws to be varied from zero to one-half inch or more, depending upon the size of wrench. Although adjustable wrenches are convenient and useful for odd-sized bolts and nuts, they are not intended to take the place of standard open-end, box-end, or socket wrenches.

Because adjustable wrenches are not built to stand excessive strain, always place the wrench on the nut so that the pulling force is applied against the stationary jaw. Adjustable wrenches can withstand the greatest amount of force when used in this manner. After placing the wrench on the nut, tighten the adjusting knurl so that the jaws fit the nut snugly.

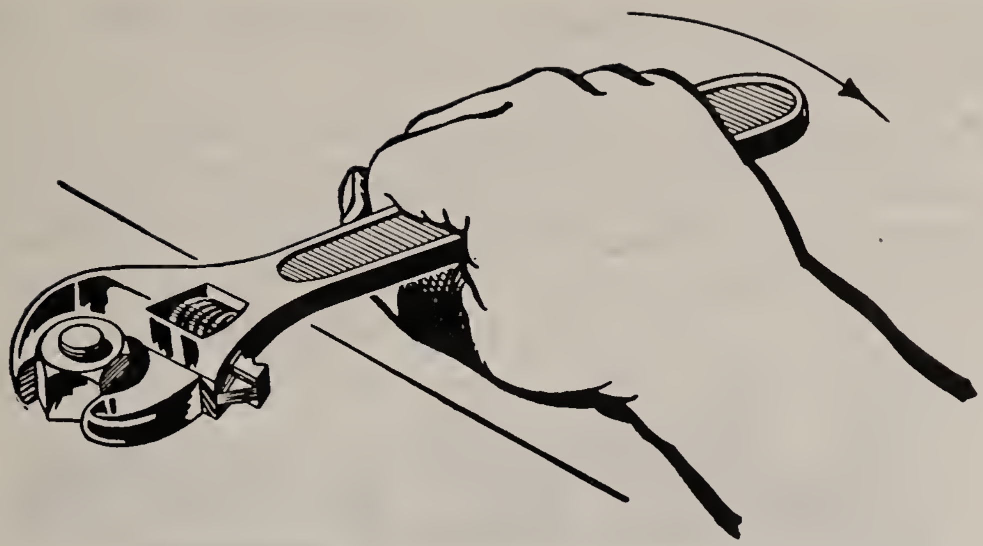


Fig. 21. Adjustable wrench and method of tightening nut.

A Stillson wrench is an adjustable pipe wrench and differs principally from other types in that it has toothed jaws which will assist in getting a firm grip on pipes and shafting. Pipe wrenches of this type will work in one direction only as noted in Fig. 22. Thus, to tighten a pipe joint, for example, the open end of the wrench must face in the opposite direction to that which loosens or unscrews the joint.

A monkey wrench is somewhat similar to the adjustable wrench except that the adjustable or sliding jaw moves parallel to the handle. The sliding jaw may be set by means of a knurled adjustment screw. Because of the ample supply of modern wrenches

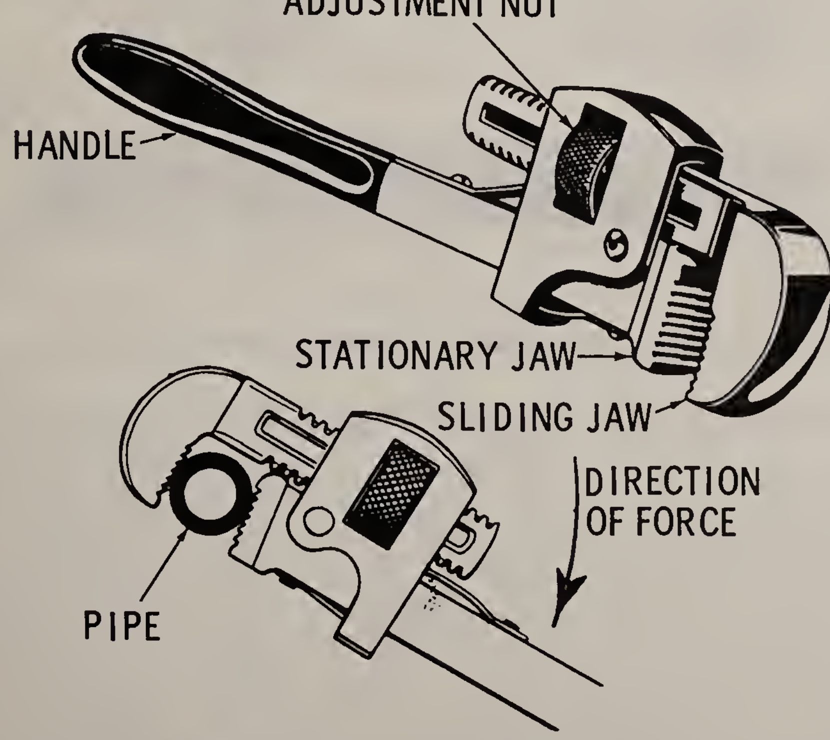


Fig. 22. Typical Stillson wrench and method of application on pipework.

available, the monkey wrench has lost much of the popularity it formerly held.

Box-end wrenches are so called because they "box" or completely surround the nut or bolt head. Their usefulness is partly based on their ability to operate in close quarters. Because of their

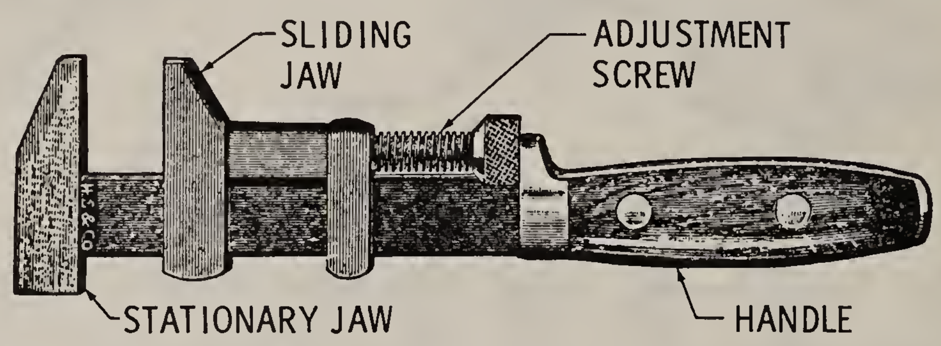


Fig. 23. Typical monkey wrench.

design there is very little chance of the wrench slipping off the nut. As noted in Fig. 24, there are 12 notches arranged in a circle. A wrench of this type is called a 12-point wrench and can be used to continuously loosen or tighten a nut with a handle rotation of only 15 degrees, compared to a 60-degree swing needed by the open-end wrench if it is reversed after every swing.

A combination wrench is simply a box-end wrench at one end and an open-end wrench at the other. This tool is made with both ends of the same size. Thus, while the box end is used for "breaking loose" nuts, the open end is used for "backing off" the nut fast after it has been loosened.

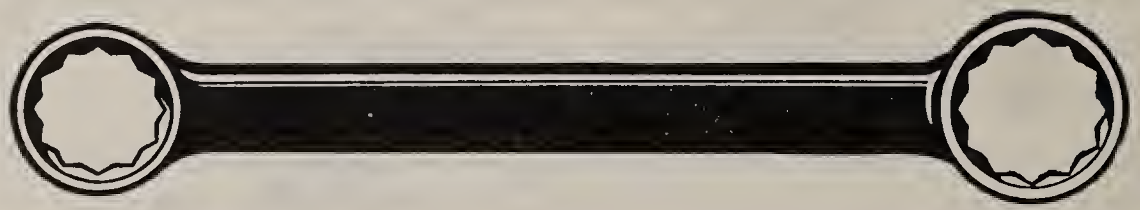


Fig. 24. Typical box-end wrench.

Socket wrenches are so called because the wrench is made in two or more parts; that is, a socket which fits the bolt or nut, and a detachable handle or lever to fit the socket in turning. The modern socket wrench is usually equipped with a ratchet mechanism similar to that used in certain hand braces for boring holes in tight corners. This permits the use of the wrench in locations where the handle travel is limited, besides making it unnecessary to shift the socket on the nut or bolt for each pull on the handle.

So-called "speed handles" or "spinners" are convenient for speeding up work when there are many nuts to remove. The speed handle is worked like a bit brace, which a woodworker uses with an auger bit to bore holes. A universal-joint handle is a useful accessory when working nuts in those places where a straight-handled wrench cannot be used. The universal joint enables the wrench handle to be worked at an angle with the socket. In addition to the foregoing, a number of handle types for use with socket wrenches have been developed, each having its particular value and adaptability for doing the work to which it is assigned.

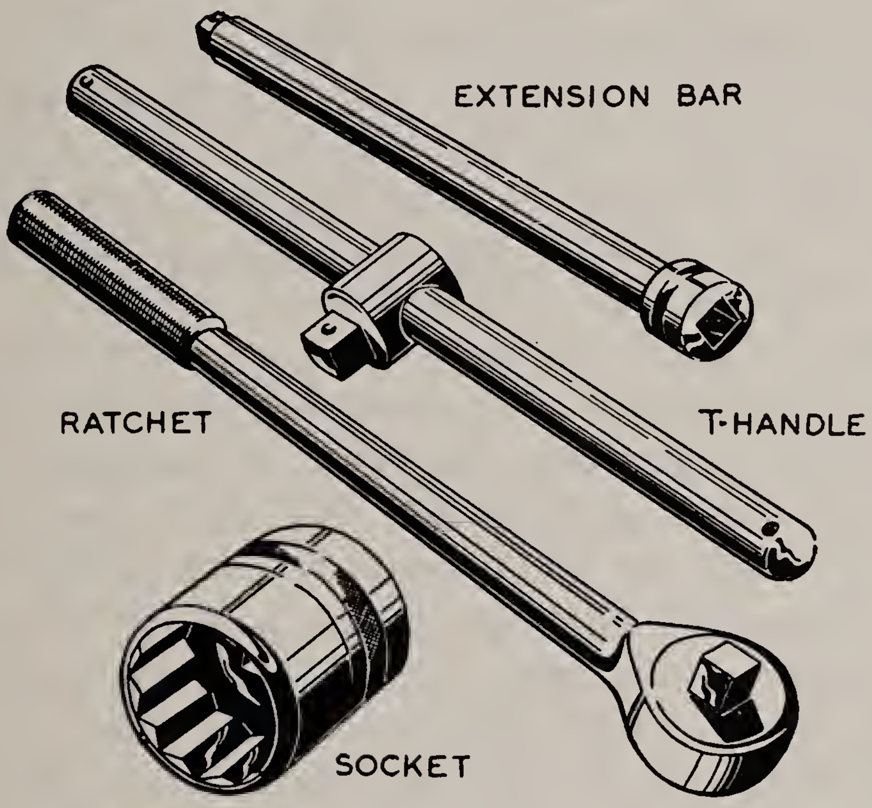


Fig. 25. Socket wrench and various handles.

How to Use a Wrench—There is very little to be said about selection of wrenches. The best wrench for a particular job is usually found by actual experience. The type of job to be done, the location and number of nuts or bolts to be worked—these are some of the considerations when selecting wrenches.

If there is ample room to swing the wrench, almost any type wrench may be used. If, on the other hand, the nut is located in a corner where there is no space, a socket wrench and ratchet handle are usually selected. It is of course important that the correct size is selected and that the wrench fit the nut exactly or is adjusted to fit the nut prior to turning the wrench. Keep wrenches

clean and free from oil; otherwise they may slip, resulting in serious injury to the operator or to the wrench.

Be careful about increasing the leverage on a wrench by putting a tube or extension on the handle, especially when tightening a nut. Increased leverage makes it easy to exert an undue strain on the bolt or wrench, resulting either in stripped threads, a broken bolt, or a broken wrench. Provide some sort of a case or kit for all wrenches. Returning them to their case after each job saves time and trouble and facilitates selection of tools for the next job. Likewise, this policy eliminates the possibility of leaving them in or on machinery or in places where they may cause damage or be lost.

It is wise to determine which way a nut should be turned before attempting to loosen it (normally counterclockwise when looking at the end of the bolt). The foregoing may seem to be very elementary, but even experienced mechanics have been observed straining at a nut in the tightening direction when desiring to loosen it.

CHAPTER 7

Miscellaneous Hand Tools

There are numerous hand tools which are not absolutely necessary in the woodworker's tool set, yet they will find numerous uses in the average shop. Among such tools are a variety of pliers, cold chisels, hand snips, burring tools, tap wrenches, taps, dies, tube-cutting tools, flaring tools, soldering irons, etc.

Pliers—The pliers most frequently used are shown in Fig. 1. Each of these has a particular purpose. Thus, for example, the side-cutting pliers are used in electrical work for cutting insulation and wires, whereas the adjustable combination pliers are used chiefly for general work such as for holding pipes of various diameters, for bending flat and round stock, etc. The various lengths and shapes of flat-nose, round-nose, and half-round-nose pliers make it possible to bend or form metal into a variety of shapes. Many special-purpose pliers are available for specific jobs.

Other pliers useful around the shop are the diagonal cutters or cutting pliers. These are short-jawed pliers with the cutting jaws at a straight angle, and are used for cutting soft wire, for removal and setting of cotter pins, and for numerous other jobs where a combined prying and cutting effect is desired. Long-nose pliers, of either the flat-nose or duckbill type, are suitable in cramped or limited quarters where other types of pliers cannot reach.

The Use and Care of Pliers—As noted in the foregoing, it is important to select and use the pliers best suited for the work at hand. Avoid using pliers on a hardened surface, as this dulls the teeth and causes pliers to lose their grip. Never use pliers for loosening or for tightening nuts, because this will usually cause damage to both nuts and pliers. Use wrenches on nuts—never use pliers.

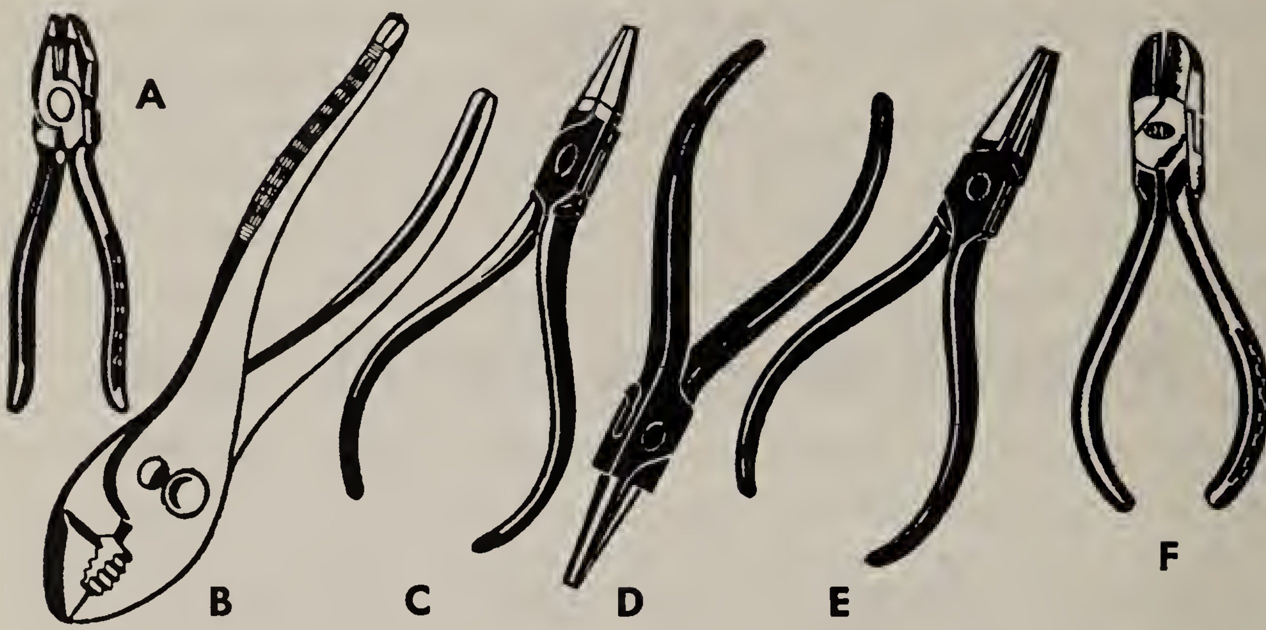


Fig. 1. Various types of pliers. In the illustration A, represents side-cutting pliers; B, adjustable combination pliers; C, flat-nose pliers; D, round-nose pliers; E, half-round-nose pliers; F, diagonal-cutting pliers.

Pliers are made in various sizes to suit individual requirements. Their overall length in inches determines their size. Thus, for example, combination pliers come in sizes from 5 to 10 inches. The best grade of pliers is made of drop-forged steel to withstand hard usage. Pliers should always be kept clean. Every now and then wash off the dirt and grit and put a drop of oil on the joint pin. Such simple precautions will cut down wear and prevent rusting.

Cold Chisels—Cold chisels are the tools used for cutting or chipping metal. They are made of high-grade tool steel with a hardened cutting edge and a beveled head at the opposite end. Cold chisels will cut any metal which is softer than themselves, or any kind of metal that can be cut with a file. The width of the cutting edge of a cold chisel denotes its size. They are classified according to the shape of the point, such as *flat, cape, round-nose* and *diamond-point* (Fig. 2).

For best results, it is important to use the correct chisel. Thus, for example, when cutting rivets or removing stock from flat surfaces and similar work, a flat cold chisel should be used. If the work involves cutting such things as keyways, narrow grooves, square corners or slots, a cape chisel should be employed. This chisel is narrow in width and can be used to chip flat surfaces that are too narrow for a flat chisel.

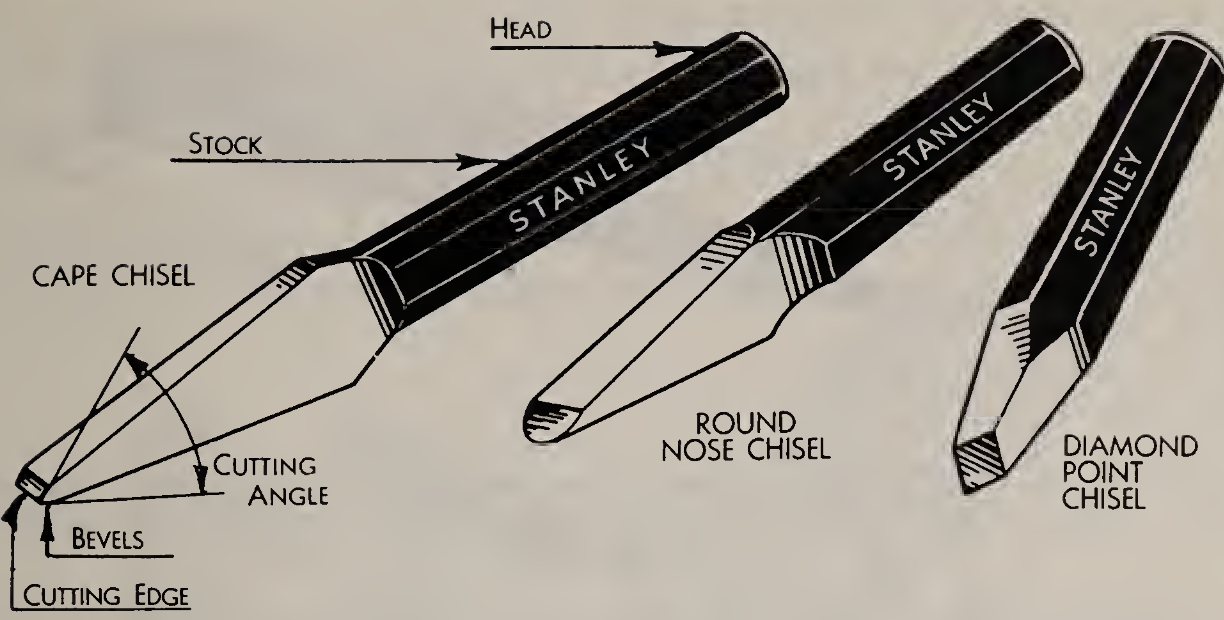


Fig. 2. Various types of cold chisels.

Fig. 3. The cutting angles of typical cold chisels. Cold chisels are ground to a cutting angle of about 65 degrees for average work. They are usually made of carbon tool steel or silicon-manganese alloy steel, tough enough to give hard lasting use, but soft enough to be filed sharp, thus avoiding the danger of burning the edge when grinding.

Round or semicircular grooves should be cut with a round-nose chisel. This tool is also used for chipping inside corners which have a curved junction. The diamond-point chisel is made square at the point, then ground on an angle across diagonal corners to make the cutting face diamond shaped. This type of chisel is used for cutting V-grooves and square corners.

How to Use a Cold Chisel—To avoid accidents when using a cold chisel, keep the head of the chisel and the face of the hammer clean and free from oil. In cutting, grasp the chisel firmly enough to hold it, but loosely enough to ease the shock of the hammer blows imparted to the hand through the chisel. Hold the chisel at an angle suitable for the cut to be made. Thus, when cutting off excess metal in flat work, for example, hold the chisel at an angle that will bring the lower bevel parallel to the surface of the work.

Grasp the hammer near the end of the handle and swing it well over the shoulder, with a free graceful sweep. After each blow of

Fig. 4. Typical flat cold chisel. Note that cold chisels are ground or filed with a bevel on both sides, forming a cutting angle of about 65 degrees for average work.

the hammer, set the chisel to the correct position for the next cut. It should always be borne in mind that the depth of the cut depends on the angle at which the chisel is held in relation to the

Fig. 5. Method of cutting with cold chisel. To cut a keyway, use a cape chisel. To avoid breaking out one end of the keyway cut both ways toward the center. When cutting an oil groove in a bearing, use a round-nose or a diamond-point chisel.

work. The sharper this angle, the deeper the cut will be. One of the common mistakes is the tendency to take too deep a cut. By constantly observing the chisel's edge rather than the head while cutting, a constant angle and an even thickness of cut will result.

When a vise is used for fastening and support of the work, it is important that the vise match the work in size or weight. The jaws of the vise should have guards made of soft materials, such as copper or brass, to protect the finish on the work. Always chip toward the solid jaw, never toward the movable jaw. Whenever possible, avoid chipping parallel with the jaws on the vise.

To cut sheet metal, mark the cut with a scriber and insert the work in the vise as in Fig. 6. Grip the work firmly in the vise with the scribed line even with or just about at the top of the vise jaws.

The waste metal should extend above the jaws as shown. Start at the edge of the work and cut along the scribed line with a sharp flat cold chisel. Use the vise jaws as a base for a shearing action.

To cut out a hole such as shown in Fig. 7, use a narrow chisel so that the shape of the cut will conform closely to the scribed line, or holes, if they are drilled. In this manner, a minimum amount

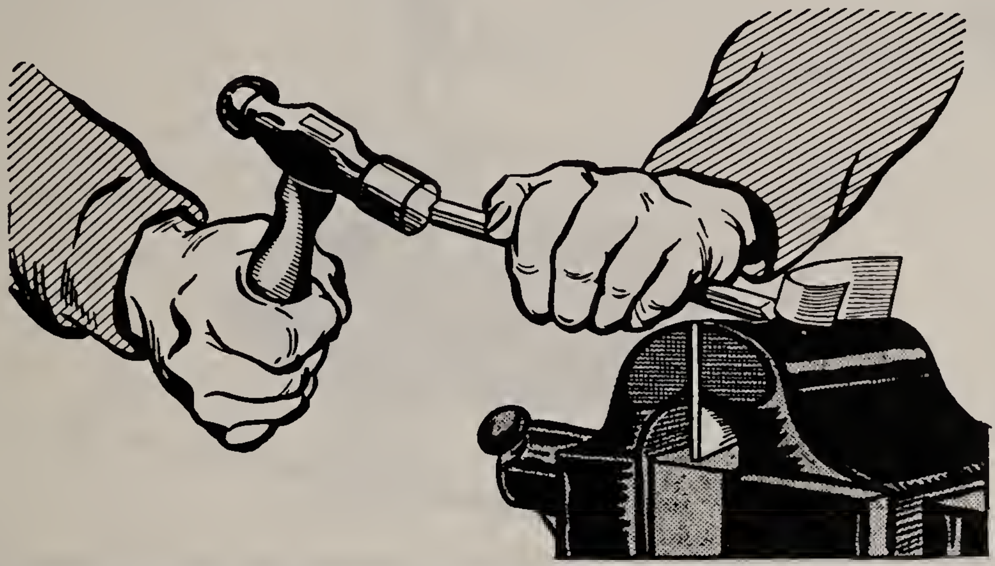


Fig. 6. Cutting sheet metal with a cold chisel. To shear in a vise, hold the chisel so that the chisel and the stationary jaw of the vise act like a pair of shears.

of filing will be necessary in finishing. Use a hammer that is heavy enough for the size of chisel used—that is, the larger the chisel, the heavier the hammer.

To avoid accidents, inspect the hammer closely prior to use. Be sure the hammerhead is firmly attached to the handle and that the wedges are driven tightly in place. When using a chisel for chipping, always wear goggles to protect your eyes. If there are other persons working close by, see that they also wear goggles or are protected from flying chips by means of a screen or other suitable enclosure. Always remember that the time to take precautions is before starting the job. After an accident has happened, it is too late for precautions.

Tinners' Snips—These snips are used mainly for cutting sheet metal up to 1/16 of an inch in thickness and have blades of various shapes and dimensions to suit different types of cutting operations.

The straight hand snips (Fig. 8) have blades that are straight and cutting edges that are sharpened to an 85-degree angle. Snips of this sort are made in sizes ranging from about 6 inches to 14

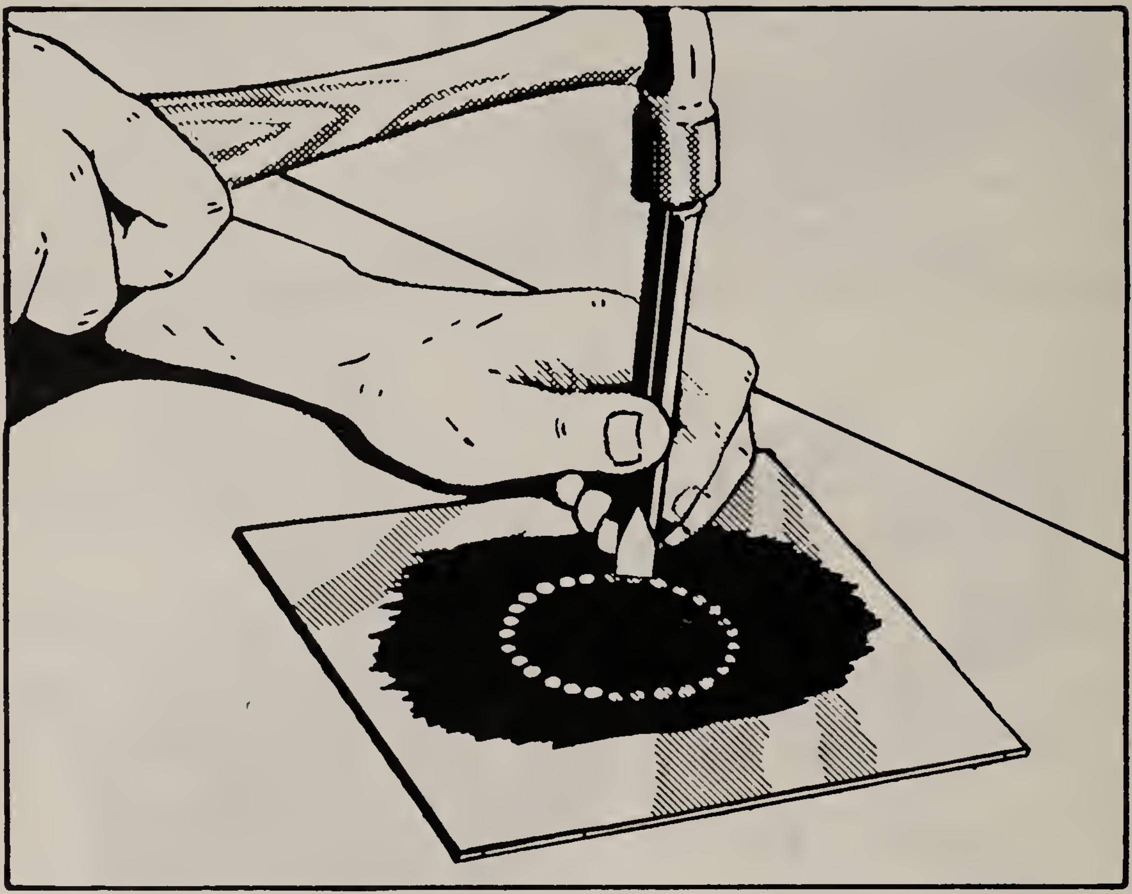


Fig. 7. The correct way to hold hammer and chisel when cutting sheet metal. To cut out a hole, use a narrow chisel so that the shape of the cut will conform closely to the line, thus the amount of filing necessary for finishing is reduced.

inches in overall length, and are used for making straight cuts. In addition to the common straight hand snips, there are snips for circular or curved cutting. Other types include *hawksbill snips, Trojan snips*, etc. Circle snips have curved blades and are used for

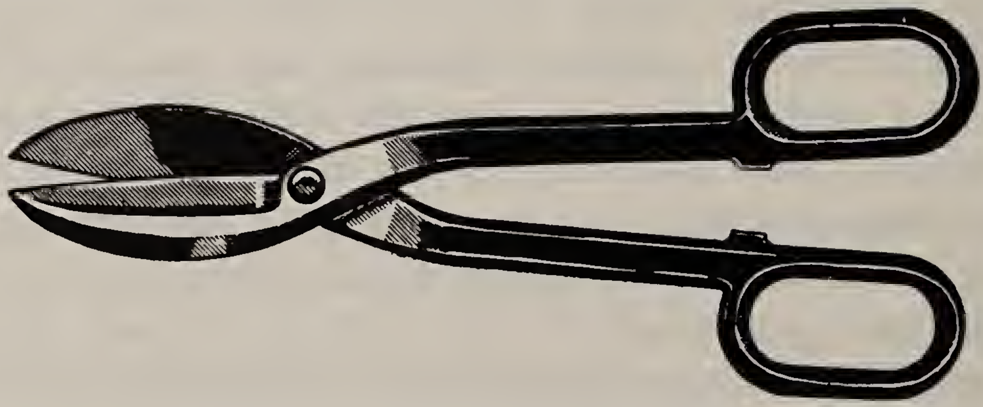


Fig. 8. Typical straight hand snips.

making circular cuts. They are available for either right-hand or left-hand use.

Hawksbill snips can cut inside and outside circles of small radii. The narrow, curved blades are beveled enough to permit sharp

turns without buckling the material. Trojan snips are slender-bladed snips used for straight or curved cutting. The blades are small enough to permit short turns. They will also cut outside and inside curves.

How to Use Hand Snips—Unlike hack saws and other forms of metal-cutting tools, the tinners' snips do not remove a portion of the metal along the cut that is made. There is a tendency, how-

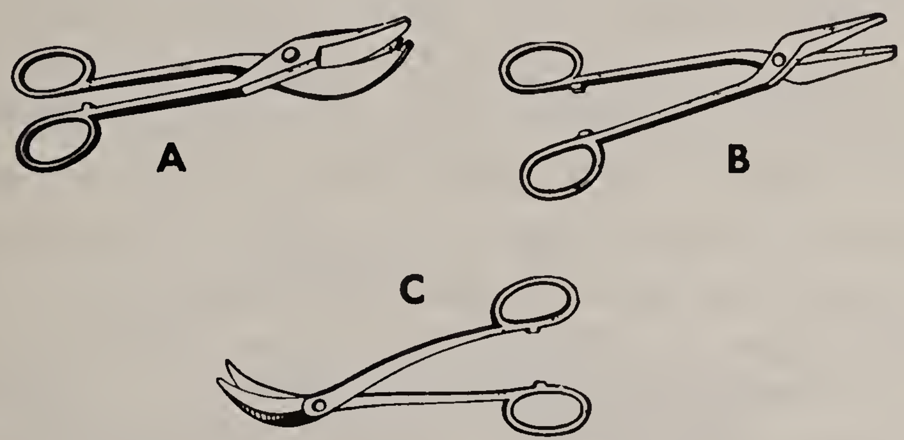


Fig. 9. Various types of tinners' snips. In the illustrations A represents circle snips; B, Trojan snips and C, hawksbill snips.

ever, to effect minute fractures along the edges of the metal during the shearing process. For this reason, it is better not to cut exactly on the layout line in an attempt to avoid too much finish work.

It is considered good practice, therefore, to leave about 1/32 of an inch for dressing. When cutting from the edge of a large sheet, experience has shown that better results are obtained when

Fig. 10. Method of cutting sheet metal with straight hand snips.

cutting from the left-hand side of the sheet. If the sheet is cut from the left, a small section of the scrap material will curl upward while the main part of the sheet will remain flat. When the

left-hand portion of the material curls upward, it provides clearance for the frame of the shears to advance along the cut.

In cutting, the cut should never be made for the full length of the blade at one time. If the points of the snips are permitted to come together, they will tear the metal as the cut is completed. Stop the cut approximately a quarter of an inch before the end of the blade has been reached and then take a new bite.

Sheet metal in excess of 1/16-inch thickness should not be cut by hand snips, because the blades may be sprung easily when too much force is applied. Also never use hand snips to cut hardened steel wire or other similar objects, because such use will dent or nick the cutting edges of the blades. To obtain best results, it is necessary that snips be oiled and properly adjusted and that the cutting edges be sharp and free from nicks. Oil the entire length of the blade and work machine oil into the adjusting bolt. Open the snips, and tighten or loosen the nut with a small wrench until the correct clearance is obtained.

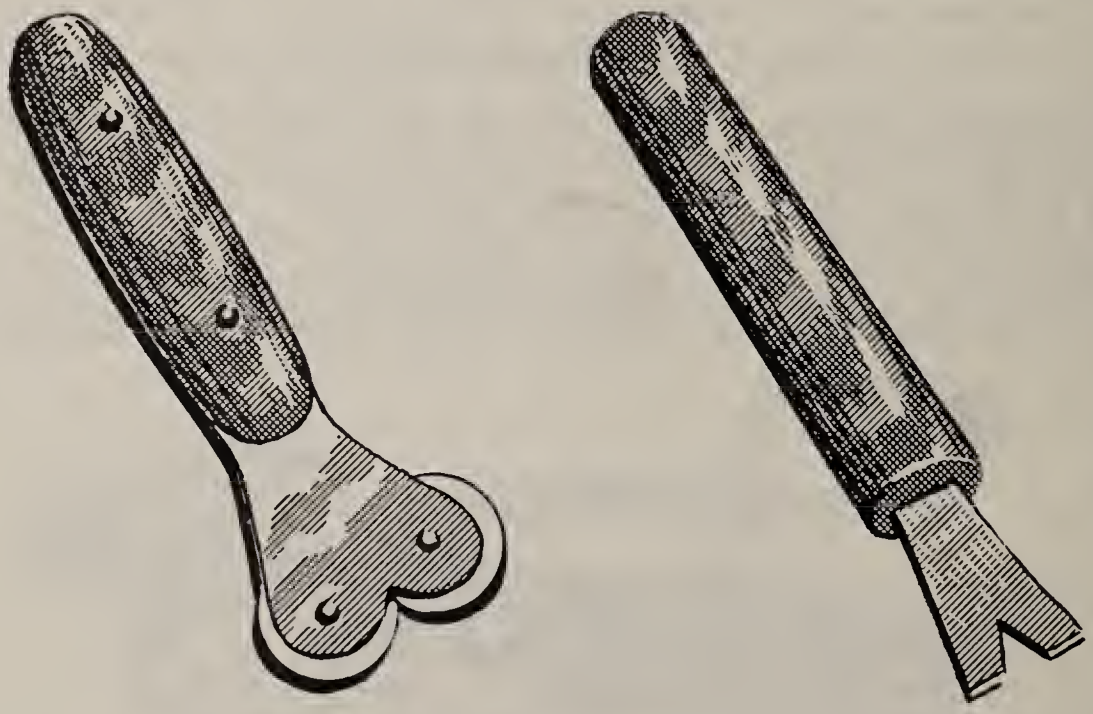


Fig. 11. Two types of homemade burring tools. Tools of this type are rather simple to make, requiring only a piece of suitable sheet metal which is cut to suit and provided with a wooden handle. The circular cutters shown should be of hardened tool steel properly ground and with sharp edges.

Dressing Metal Sheets—After the metal has been cut to its approximate size, a finishing known as "dressing" is performed. This consists in removal of burrs and ragged edges which may

remain as a result of the cutting. This can be done with files, burring tools, or edge scrapers. Burring tools of the type shown in Fig. 11 are easily made in the shop and will serve just as well as those purchased in the hardware store. To use the burring tool, simply run it along the edge of the metal with a slight pressure as shown in Fig. 12. This is a very useful tool which will greatly assist in removing burrs from the edge of the metal and at the same time it will produce a slight bevel on the finished material without marring or scratching the surface.

Tap Wrenches, Taps and Dies—These tools are used for cutting external and internal threads in metal objects. There are

Fig. 12. The burring process as applied to sheet metal.

many forms of wrenches for taps and several forms of stocks for dies. The diestock for round, split dies, and the T-handled and adjustable tap wrenches shown in Fig. 13 will provide the necessary holding tools for work in either open or confined spaces.

Taps are used to cut internal threads, and dies are used to cut external threads. They are classified according to the type of screw thread they form, such as N.F. (American National Fine) and N.C. (American National Coarse). Other classifications are according to the diameter of the screw thread formed and according to the number of threads per inch.

How to Use Taps—Fig. 14 represents various taps which are usually purchased in sets of various diameters and styles. The taper tap may be used for internal threading where the work permits the tap to run entirely through. The diameter of this tap

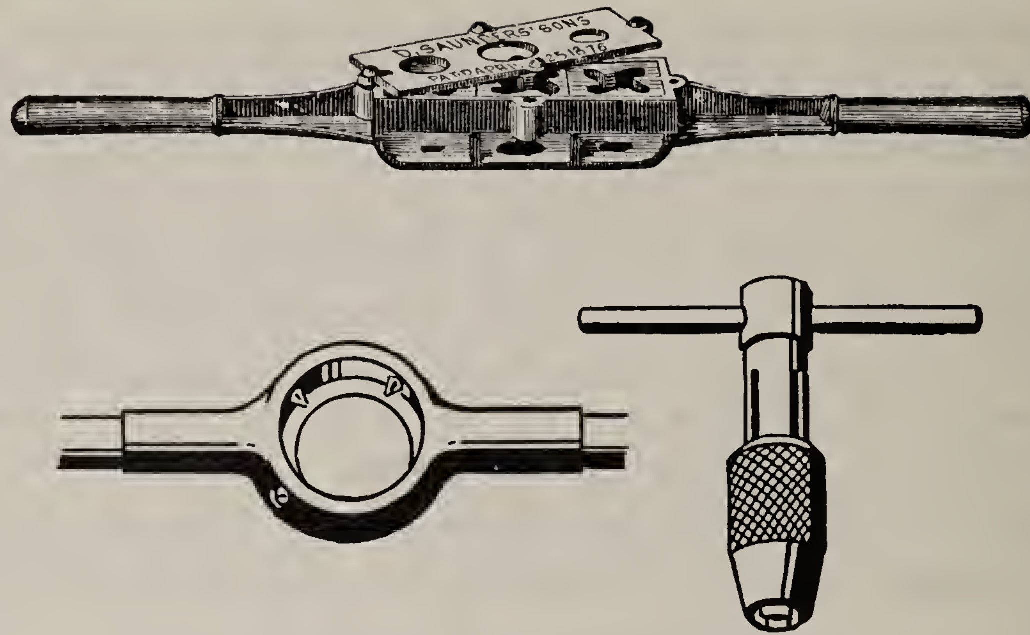


Fig. 13. Typical die stock and wrenches.

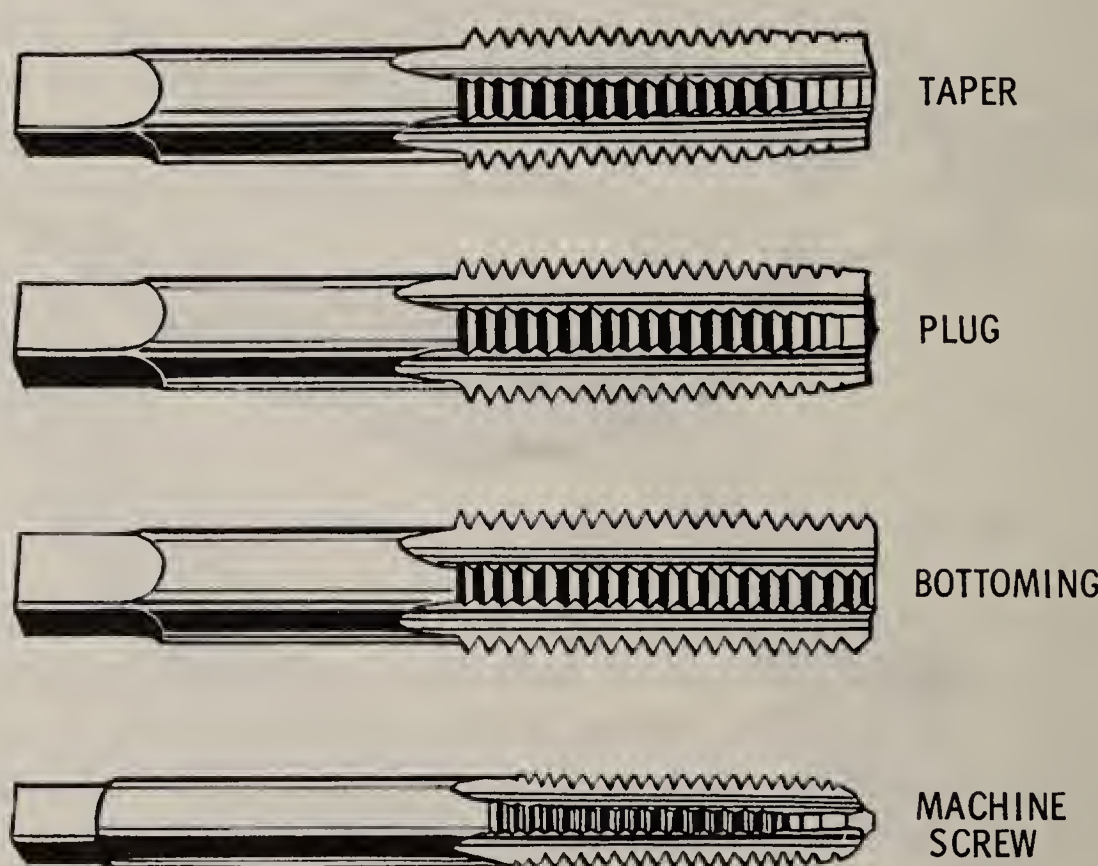


Fig. 14. Various types of hand taps. Taper, plug, and bottoming taps for screw threads usually come in a set.

gradually increases from the starting end. When the taper tap cannot be run entirely through the work, it is usually followed by a plug tap of the same size after the taper tap is removed.

If it is desired to have full-diameter threads all the way to the bottom of a hole, follow the plug tap with a bottoming tap which has the same diameter over its entire length. The size of drill for

drilling a hole to be threaded is determined by the diameter of the tap minus one and one-half times the depth of the thread used. Size of tap drill to use can also be obtained from a table.

A lubricant will help to obtain a smooth, clean-cut thread. Lard oil is generally preferred for steel; kerosene is used for aluminum or aluminum alloy. A lubricant is not needed for brass.

How to Use Dies—To cut external threads on bolts and pipes, threading dies are used. These are made in a variety of forms, of which the nonadjustable and adjustable split type are most commonly used. The tool for turning and guiding the die through the work is termed the "stock." The stock consists principally of two projecting handles, attached to the stock which provides the housing for the die. In addition the stock assembly contains leader screws or bushings which give additional support to the die, insuring a correct thread when cutting.

The greatest difficulty experienced in threading is caused by the use of dies which are inadequate to perform the work expected of them. For good results in threading, the die must be made to cut freely, not push. A die which pushes the metal off, instead of cutting it freely, causes the threads to break out of the die. Proper design of a die includes consideration for lip, chip space, clearance, and lead of throat.

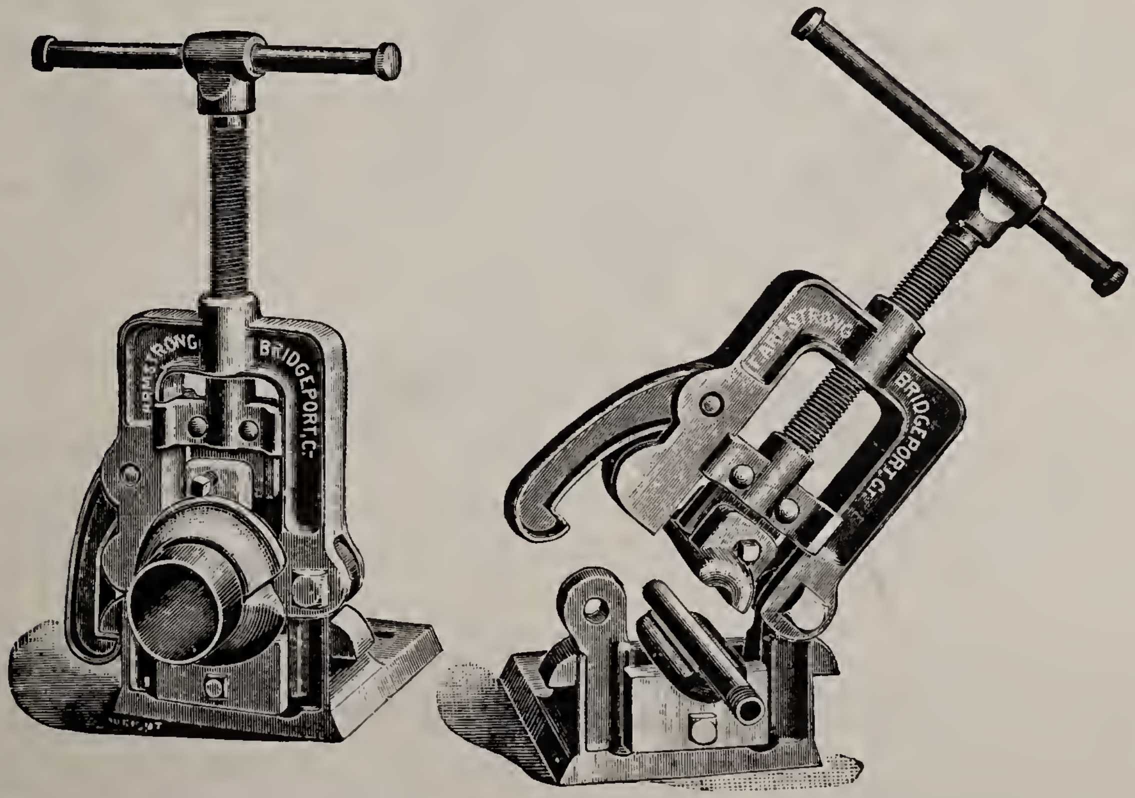


Fig. 15. Pipe vise fitted with jaws for various diameters of pipe. These jaws do not have teeth but hold the pipe firmly by frictional grip.

A special tool for holding pipes and bolts to be threaded is known as the pipe vise. It consists essentially of a plain or hinged U-shaped piece containing the clamp screw, and serving as a guide for the upper jaws. The upper and lower jaws are provided with a series of rectangular teeth to prevent the pipe from turning. A typical pipe vise is shown in Fig. 15.

Tube Cutting and Flaring Tools—Tube cutting and flaring tools are used for cutting and flaring of soft metal tubing.

Tube cutting by means of a cutter is illustrated in Fig. 16. In operation, the tubing is placed between the rollers and the cutting wheel. Screw down the cutting wheel lightly against the tubing at the point where the tubing is to be cut. Then rotate the cutter around the tube, at the same time maintaining a light, even pressure on the cutting wheel by means of the screw adjustment. The proper direction of rotation is with the handle of the cutter moving toward the open side, as noted by arrows in Fig. 16. This method of cutting tubing is preferred to cutting by hack saw, because it insures perfectly square cuts with a minimum of burring.

Flaring a piece of tubing is an operation that spreads or enlarges the opening to form a sealed seat when the ends are joined together by a fitting and flare nut. The efficiency and convenience of a flared joint is determined by the manner in which the tubing is flared or spread at the end. For this reason, it is important that flares be made clean and of the correct form and size. Before

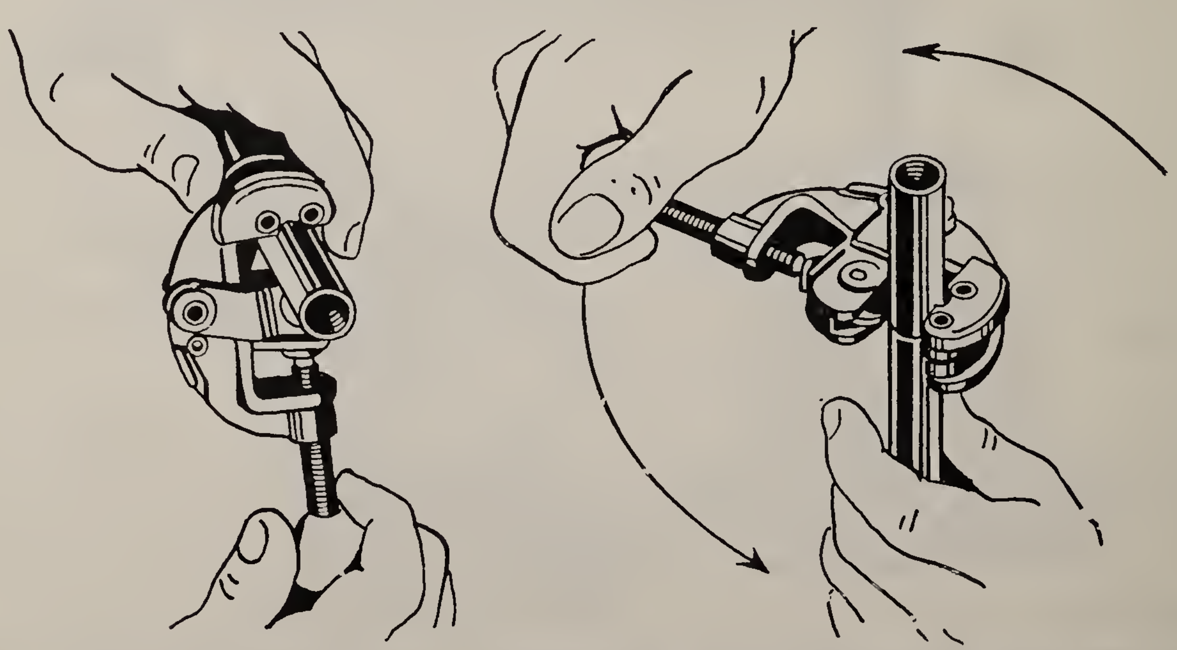


Fig. 16. Typical tube-cutting tool and method of cutting.

commencing to make a flare, be sure that the tubing is properly cut; that is, its end must be straight, square, and smooth. A perfectly round tubing cross-section must be maintained. The tubing must, in addition, be free from all burrs, scratches, nicks or other surface defects.

How to Make a Flare—To make a flare with the combination flaring tool (Fig. 17) first clamp the tubing securely in the proper flared hole. The end of the tubing should project above the face of the tool just about one-third of the depth of the flare recess. Next, move the flaring pin over the tube and strike a number of light blows with a hammer until the tube is properly flared.

If the flares are too long, too short, or cut at an angle, the result will be an incorrect joint, causing leakage and failure at the fitting. Thus, when tubes are flared too short, the full clamping area

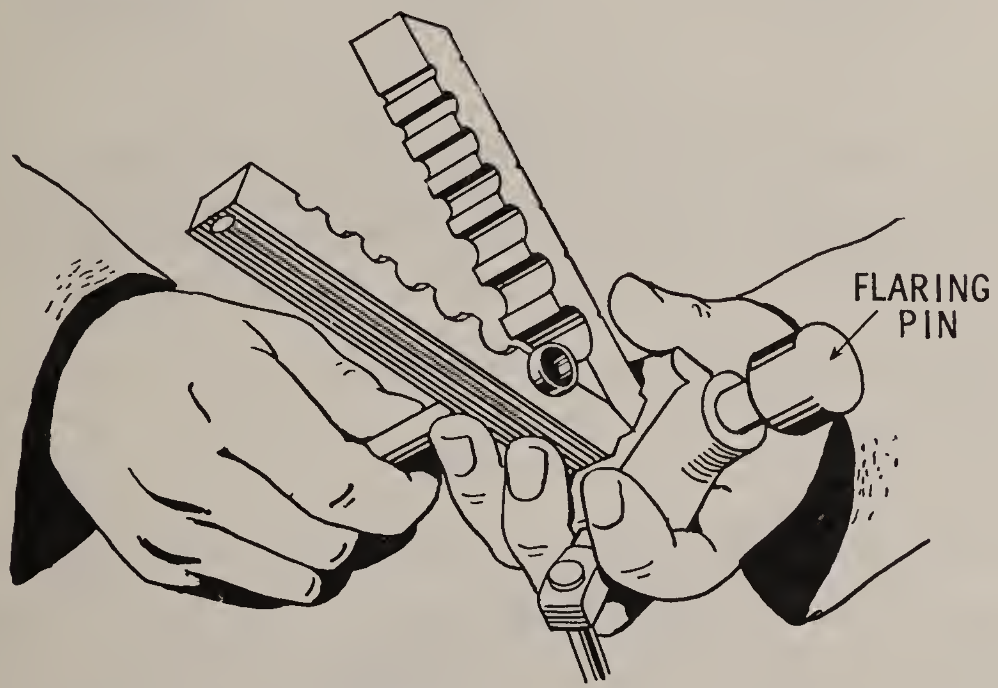


Fig. 17. Flaring tool for use with various tube diameters.

of the fitting is not utilized. Because of the small area of the tube that is clamped, the flare may be squeezed thin. Such joints do not offer maximum security against leakage and breakage at the flare.

Tubes that are flared too long, on the other hand, will stick and jam on the threads during assembly. They are likely to seat against the bottom of the coupling instead of on the tapered seat. When the tube is cut at an angle, the flare will not be concentric at its top, resulting in misalignment with the fitting surfaces and eventual

failure of the fitting. The various faults in tube flaring are illustrated in Fig. 18.

Soldering Tools—Soldering may be defined as the process of joining two metal parts together by a metal called solder. Solder is an alloy of lead and tin and has a lower melting point than either of its components or the metals to be joined. Solders which melt readily are termed soft solders, while those which melt at a red heat are termed hard solders. The process of soldering con-

Fig. 18. Incorrect flares for tube connections.

sists of cleaning the surfaces to be joined, and heating them to the soldering temperature by any suitable means, such as:

1. Soldering irons (plain and electric).
2. Gas flame.
3. Blowtorch.

The essentials for any soldering job are: (a) clean metal surfaces; (b) correct flux; (c) good quality solder; and (d) sufficient heat. The purpose of the soldering flux (which is generally rosin or zinc chloride) is to remove any grease or oxide present on the materials to be soldered. The solder is then melted into the joint and the joint smoothed over and finished by the use of a copper-tipped soldering iron or other heating means.

Soldering irons, such as shown in Fig. 19, are generally used for small soldering work. Made with a copper tip, these tools must be properly "tinned" or coated with solder and maintained in a clean condition before they can be used efficiently. Tinning consists of filing the surface of the tip to a bright, smooth finish, heating it to a temperature sufficient to melt the solder, and then

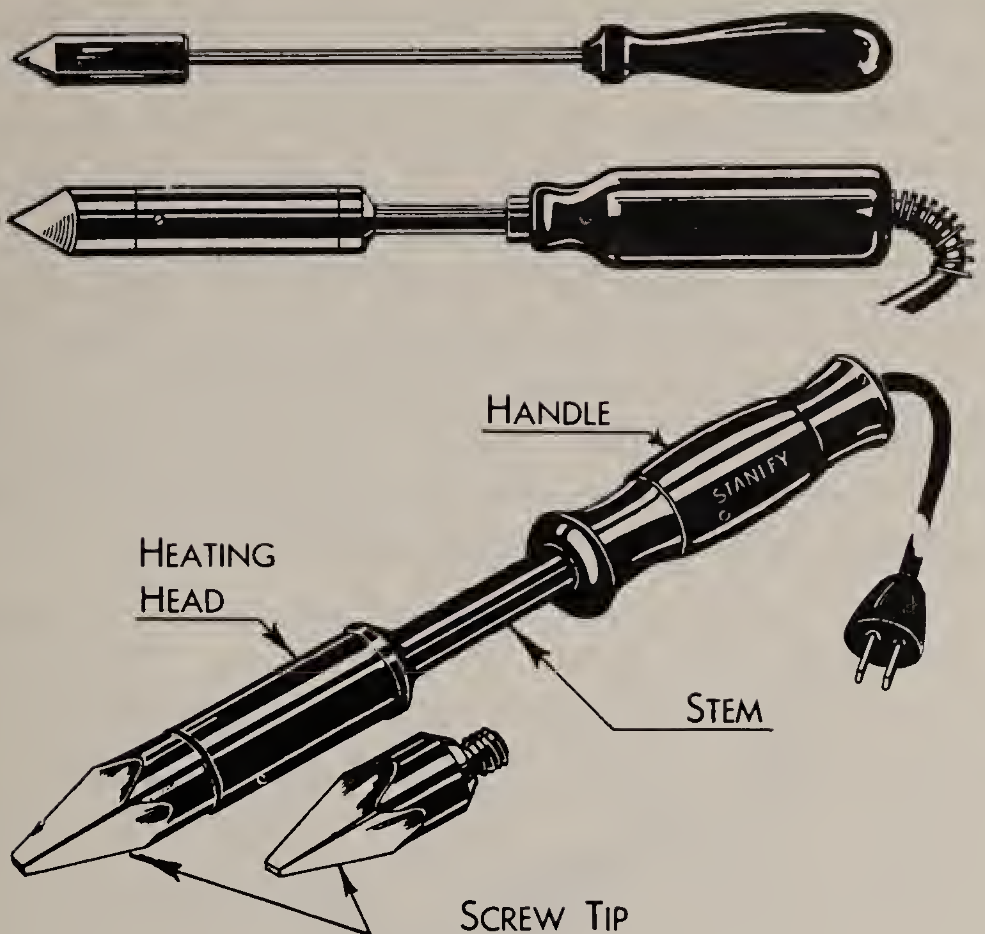


Fig. 19. Various types of electric and conventional soldering irons. These are used in industrial plants, radio-repair shops, tinning shops and other places where production soldering is required.

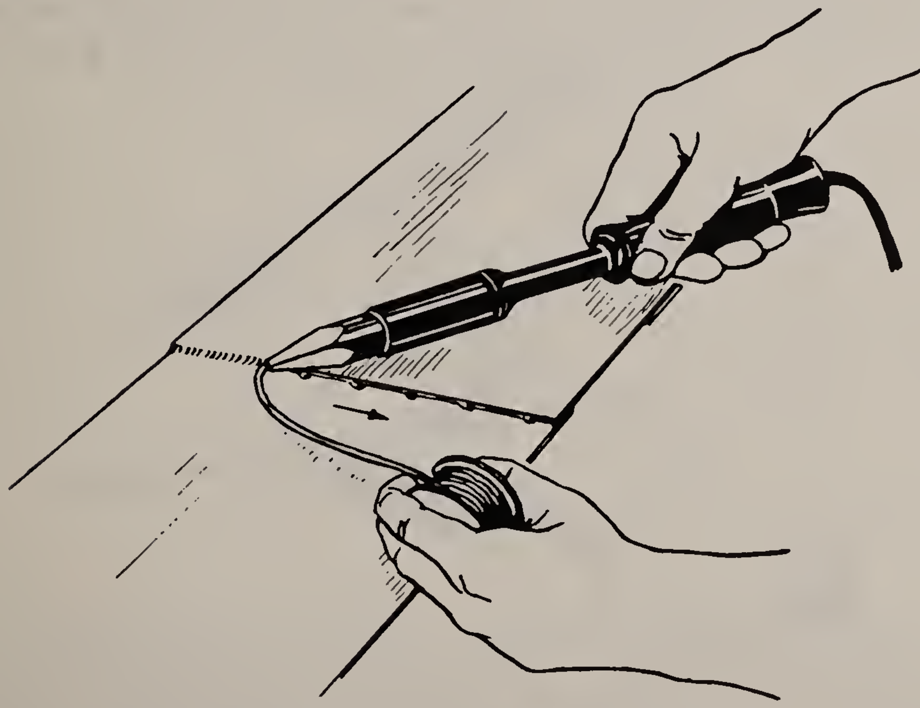


Fig. 20. Tin-plate soldering with core solder. Before soldering, clean tin and apply flux. Tack work with drops of solder to hold it together. Apply solder directly to the work, particularly when core solder is used because the flux may evaporate and lose its strength before it does its work.

applying a small portion of solder and rosin to the surface of the tip. This process will form a tinned surface on all sides.

Soldering irons are used for splicing wires, as in electrical work, and for soldering sheet metal together where the sheets are either lapped or locked together and present a surface over which the soldering tool may be drawn. Methods of using the foregoing types of soldering tools are illustrated in Figs. 20 to 22. Here the iron is heated (by conventional or electric means) to a temperature sufficient to melt the solder quickly and is drawn along the edges to be joined at such a rate that the momentary high temperature of the edges results in the formation of a tight joint.

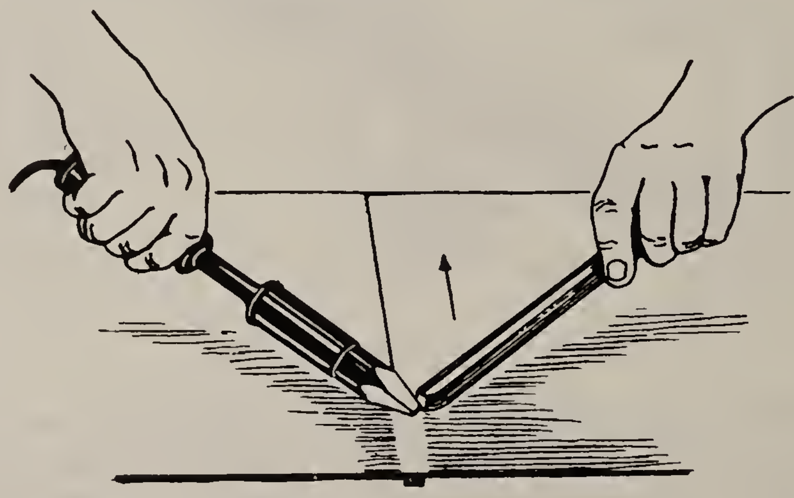


Fig. 21. Tin-plate soldering method. To run a seam or lap joint, apply flux and heat the work with the iron. Apply solder directly to work or under the iron. Start at the point farthest away and draw the iron in the direction shown, feeding solder as the work progresses. The flux and heat will draw the solder into the joint.

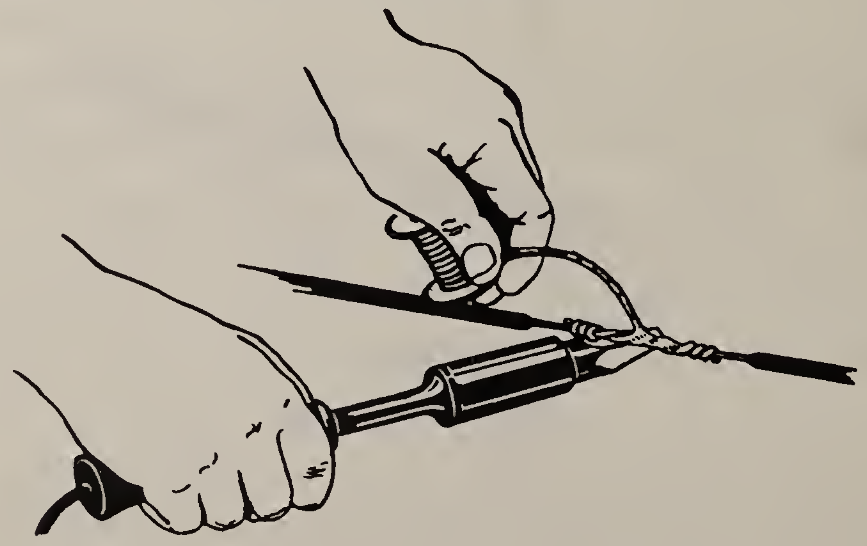


Fig. 22. Method of wire soldering. To make a soldered joint of this type, clean and twist the wire together as illustrated. Apply flux and hold surface of tip against twisted wires. Apply solder to heated work from the top, thus permitting the fluid solder to flow between the wires by action of gravity.

The soldering iron is also used in work where there is a fire hazard and the use of a flame or molten solder poured over the surface is prohibited by fire ordinances. Electric soldering irons are very handy tools around the shop, and consist of a built-in coiled resistance wire and accompanying heater cord. Certain types of electrically heated irons are equipped with a replaceable copper tip which is attached to the iron proper by means of a screw head or by a setscrew. The rating of electric soldering irons is usually around 100 watts, which means that the current consumption when used on a standard 115-volt circuit is somewhat less than one ampere. All electric soldering irons not equipped with thermostats can operate on either alternating or direct current.

The blowtorch is used where the metals to be joined together are not of suitable shape for the use of a soldering iron or where the heat generated by the iron is insufficient. Here, soldering is accomplished by playing the flame of a gasoline, kerosene or alcohol blowtorch directly on the surfaces, and then applying the cold solder in bar or core form of small cross section. The heated surface melts the solder.

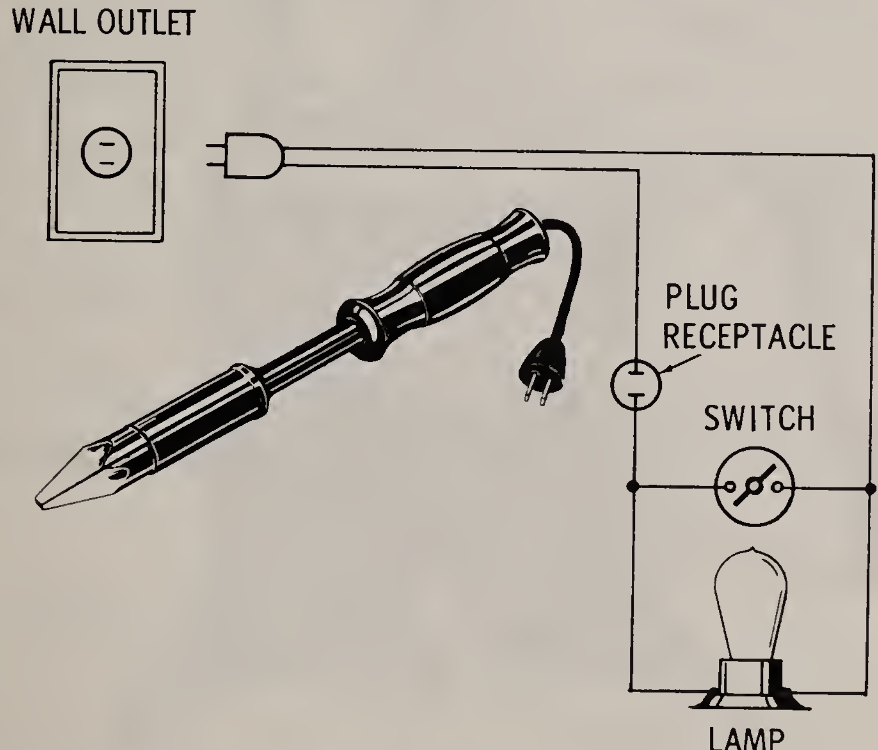


Fig. 23. Circuit diagram showing method of preventing electric soldering iron from overheating when iron is used only intermittently. The circuit is arranged in such a manner that when the switch is in a closed position, the iron receives the full normal voltage from the wall outlet. When the soldering process is interrupted, opening of the switch connects the resistance of the lamp in series with that of the iron resulting in a considerable drop in voltage and preventing the iron from overheating. The size of the lamp depends upon the wattage of the soldering iron.

Miscellaneous Hand Tools

A typical gasoline blowtorch is shown in Fig. 24. To operate the torch, fill the tank about two-thirds full of clean unleaded gasoline. After careful tightening of the filling cap and valve, operate the pump until sufficient air pressure is built up in the tank to cause the gasoline to flow when the valve is opened.

With the valve open, liquid gasoline will flow from the jet of the torch and drip into the priming pan. When the pan is partly filled, close the valve and ignite the gasoline with a match. As soon as the nozzle becomes hot, open the valve slightly again, allowing the gasoline vapor which has been formed to flow from the nozzle.

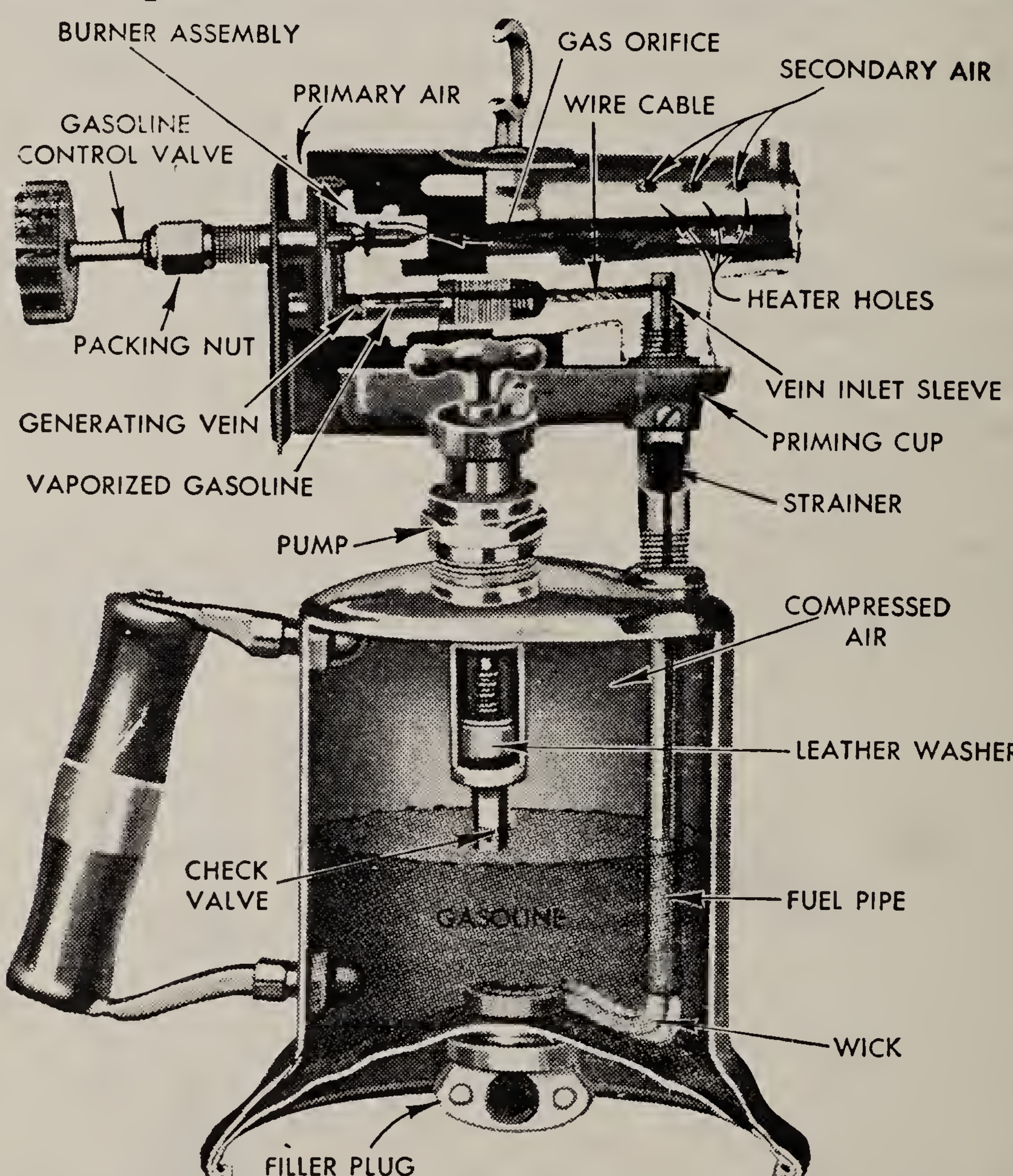


Fig. 24. Typical gasoline blowtorch.

It should then burn with an almost colorless flame. By turning the valve stem, the flame can be adjusted to any desired intensity. There is very little maintenance in connection with its operation, provided that only clear unleaded gasoline is used.

Soldering Fluxes—As previously noted, flux used in soldering has a cleansing effect, retards oxidation, and aids fusion. The fluxes ordinarily used for soft soldering are solutions or pastes that contain zinc chloride. The solvent or other medium holding the flux material is evaporated by the heat of the soldering operation, leaving a layer of the flux on the work.

At the soldering temperature, the solid flux is melted and partially decomposed, with the liberation of hydrochloric acid. This acid then dissolves the oxides from the surfaces of the solder and the work. The melted flux also forms a protective film on the work that prevents further oxidation from taking place.

Because zinc chloride fluxes have a corrosive action, it is sometimes necessary to employ a noncorrosive flux for work where the last traces of the flux cannot be removed by washing after soldering is completed. Rosin is the most commonly used flux of this type.

Various fluxes are used when soldering different kinds of metals. Zinc chloride will clean and prevent oxidation when black iron is being soldered. Another flux, muriatic acid, is the commercial form of hydrochloric acid. This raw acid is used as a flux when soldering galvanized iron, but it is a good practice to add a little zinc to the raw acid to prevent blackening of the galvanized iron around the soldered joint.

Rosin flux is used on new tin plate and in all electrical work because it is noncorrosive. Rosin, however, acts only to prevent oxidation and does not clean the work. Therefore, raw acid must be used as a cleanser on new tin plate, while rosin is used in the actual soldering process. Never use acid flux on any electrical work.

CHAPTER 8

Sharpening of Woodworking Tools

Successful woodworking depends upon proper tool maintenance, the most important step of which is the tool sharpening process. There are two separate operations involved in sharpening woodworking tools: namely,

1. Grinding.
2. Whetting.

Practically everyone knows the added pleasure that working with properly sharpened tools gives, but many try to maintain the edge of their tools by whetting when the original shape of the cutting edge is worn out or nicked and requires regrinding. In addition to a set of files, the tools used for sharpening are:

1. Grinder.
2. Oilstone.

Grinder—A grinder consists essentially of a horizontal spindle, the ends of which are threaded and fitted with flanges to take the grinding wheels. The spindles are often continuations of the motor shaft, in which case the unit is direct driven. Other models may employ the conventional belt drive.

The composition of a grinding wheel consists of the cutting material or abrasive (usually called the grit) and the bond. The cutting quality of a wheel depends chiefly on the grit and the hardness of the bonding material. The object of the bond is to hold the particles of the grit together with a proper safety factor.

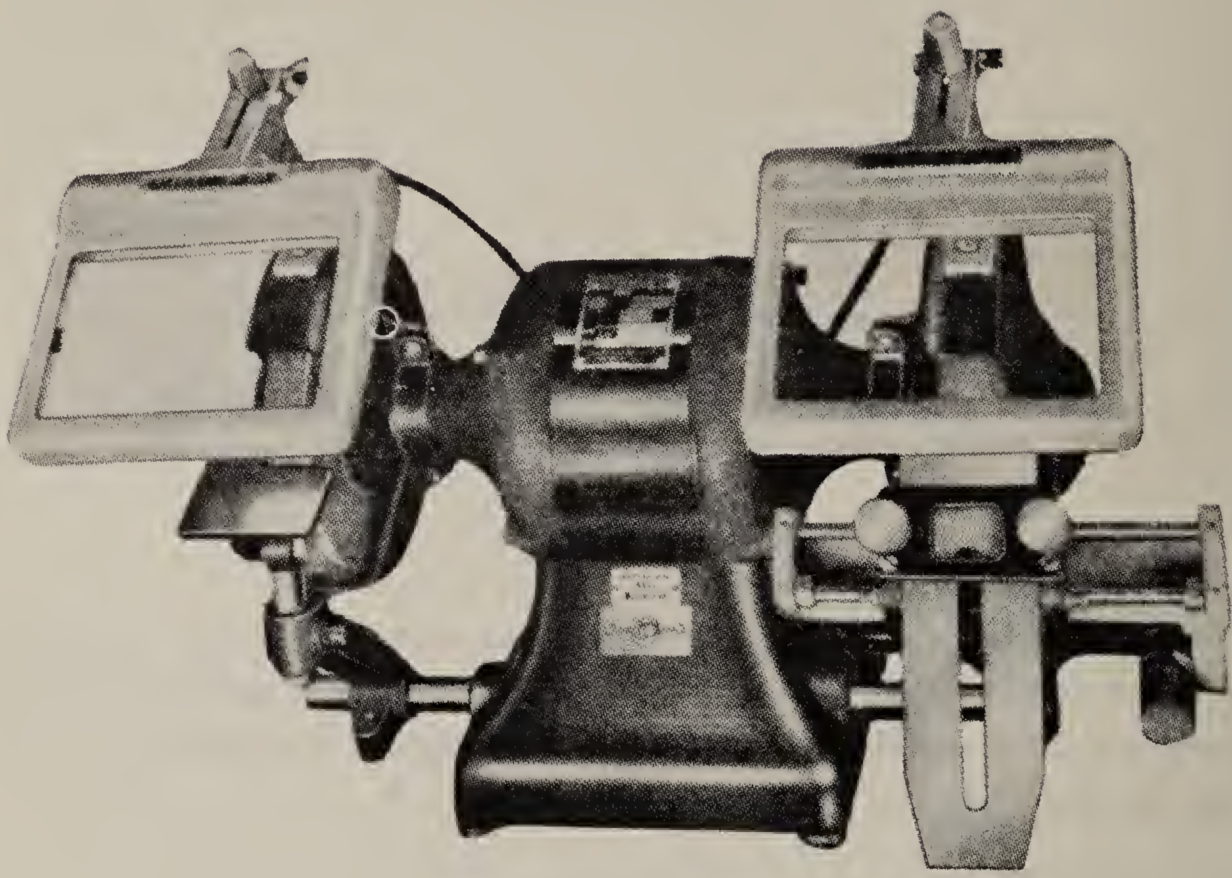


Fig. 1. Standard tool grinder.

A grinding wheel is called hard or soft according to the tenacity with which the bond holds the particles together. A grinding wheel is said to be too hard when the bond retains the surface or cutting particles until they become dull, and too soft when the particles are not held long enough to prevent undue wear of the wheel. Wheels are bonded by the vitrified, silicate, electric, and rubber processes. The size of the grinder is commonly taken from the diameter of the abrasive wheel or wheels. For example, a grinder having 7-inch-diameter wheels is termed a "seven-inch grinder."

Abrasive wheels are usually selected with reference to their "grit." A grinding wheel for tool sharpening should preferably be an aluminum oxide wheel of about 60 grit and of minimum hardness. A coarse, soft-grit wheel will remove material more rapidly than one with a finer grit, but the surface produced will be rough compared with that produced by the other. Hence a wheel suitable for grinding woodworking tools should be of fine grit and it should also be soft.

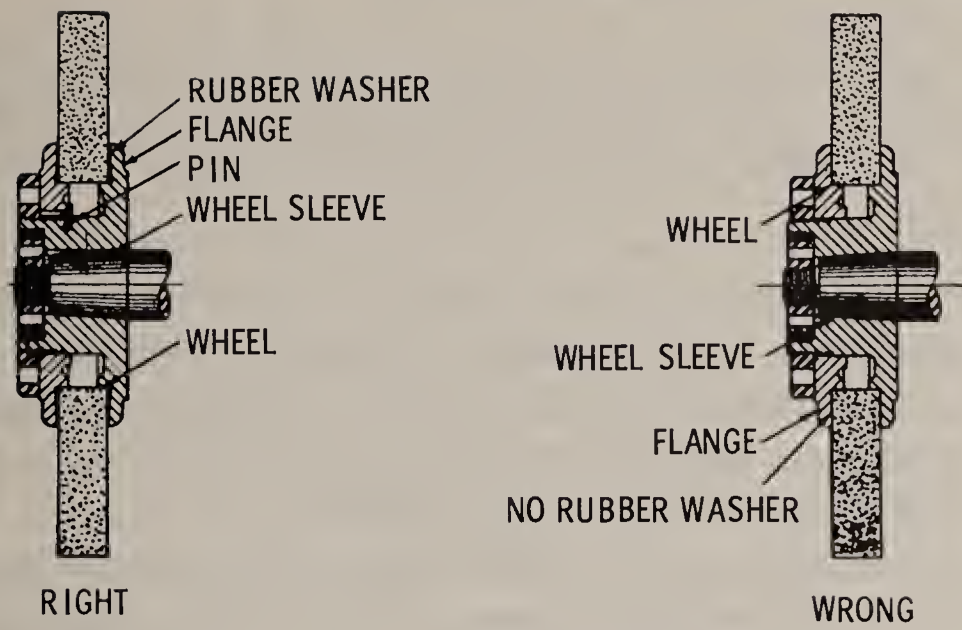


Fig. 2. Method of grinding-wheel installation. Great care should be observed when mounting grinding wheels to see that flanges of the same diameter as the spindle are properly placed. The hole in the outer flange should be an easy sliding fit on the spindle or arbor. All flanges should be recessed at the center to a depth of at least one-sixteenth of an inch in order that they may bear at the outer edges only. The nuts should be tightened only enough to hold the wheel firmly, because excessive tightening may damage the wheel.

In the use of abrasive wheels for grinding woodworking tools, it should be noted that the high surface speed generates considerable heat, hence the tool should be held lightly against the stone and frequently dipped in water, otherwise it will be burned. If a wheel running at a nominal speed has a tendency to burn the tool, the wheel should be closely examined to see if it is in need of dressing. The power required to operate a six- or seven-inch grinder is approximately ⅓ horsepower. When a unit is direct driven, the motor must run at about 3,400 rpm in order to give the grinding wheel an efficient rim speed. To get best results, the wheel should run at a surface speed of from 5,000 to 5,500 feet per minute, but for tool grinding, or when running the wheel in water, a slower speed is advisable.

Example: What will be the surface speed of a 6-inch-diameter grinding wheel when directly connected to a motor running at 3,400 revolutions per minute?

Solution: If it is remembered that the circumference of the wheel is π times its diameter, and that for each revolution of the motor shaft the grinding surface of the wheel must travel a distance equal to its circumference, we obtain the surface

speed as: $3{,}400 \times 6 \times \pi/12$ or 5,340 feet per minute. It should be noted that the surface speed of any grinding wheel may be similarly calculated provided that the motor speed is known.

An essential feature of all grinders is the wheel guards. These should enclose the wheel as fully as possible in order to prevent abrasive chips or larger fragments of the wheel from being thrown at the operator. Extra eye protection is desirable when rough grinding and wheel dressing are performed.

Oilstones—These are used after the grinding operation to give the tool the very keen edge necessary to cut wood smoothly. The oilstone is so called because oil is used on a whetting stone to carry off the heat resulting from friction between the stone and tool and to wash away the particles of stone and steel that are worn off in the sharpening process. The process of rubbing the tool on the stone is called "honing." There are two general classes of oilstones:

1. Natural.
2. Artificial.

Natural Oilstones—There are two general classes of natural stones grouped according to the locality in which they are found, as: (a) Washita, and (b) Arkansas. *Washita stone* is found in the Ozark Mountains of Arkansas, and is composed of nearly pure silica, very similar to the Arkansas, but much more porous. It is known throughout the world as the best natural stone for sharpening carpenters' and woodworkers' tools. Its sharpening qualities are due to small, sharp-pointed grains of various grades, from perfectly crystallized and porous grit to vitreous flint and hard sandstone. The sharpness of grit depends entirely upon its crystallization. The best oilstones are made from very porous crystals.

Lily White Washita is the best selection or grading of natural Washita, perfectly white in color, uniform in texture and nicely finished. *Rosy Red Washita* has an even, porous grit somewhat coarser than the Lily White grading and is therefore faster cutting. No. 1 Washita is a good oilstone for general use, where a medium-priced stone is wanted It is far superior to the many cheap, so-

called oilstones on the market that are only sandstones with a polished face, but it is not as uniform as the Lily White.

Arkansas Oilstone is composed of pure silica crystals, microscopic in size, and silica is among the hardest of known minerals. So hard and perfectly crystallized is the Arkansas stone that it is nearly sixteen times harder to cut than marble. The hardest of steel tools with the finest blades may be sharpened on the Arkansas stone without grooving the stone. Arkansas stone is prepared for commercial purposes in two grades, hard and soft.

Hard Arkansas is much harder than steel and will therefore cut away and sharpen steel tools. The extreme fineness of texture makes it a slow cutter, but a perfect sharpener. *Soft Arkansas* is not quite as fine grained and hard as the Hard Arkansas but it cuts faster and is better for use by wood carvers, file makers, and patternmakers, and is used by most workers of hardwood.

Artificial Oilstones—These are made of aluminum oxide, silicon carbide, emery, and other artificial abrasives and are largely used in place of natural stones because they cut faster and may be made in any degree of fineness and smooth texture. Aluminum oxide oilstones are made by fusing bauxite, a highly aluminous clay, in an electric furnace at about 3,000 degrees F. The crystals are usually brown in color, but some types are made gray and white. They are not as hard as silicon carbide but are much tougher.

Silicon carbide oilstones are made by fusing sand and coke at high temperatures. The resulting crystals are next in hardness to the diamond, but are brittle as opposed to those of aluminum oxide. The color ranges from black-gray to blue-green. Both aluminum oxide and silicon carbide are used widely and are sold under various trade names, such as Aloxite, Alundum and Lionite (aluminum oxide) and Carborundum, Crystolon and Carsilon (silicon carbide).

How to Sharpen Wood Chisels—Chisels, in common with other sharp-edged tools, are first placed on a grindstone or grinding wheel in order to bring the bevel to the correct angle and to grind out any nicks that may be in the cutting edge. The grinding wheel used should be an aluminum oxide wheel of about 60 grit and of minimum hardness. When grinding, keep the tool cool

by constantly dipping it in water. When blue spots appear on the edge of the tool, temper is being drawn.

Wood chisels should be hollow-ground. Project the chisel straight into the wheel to remove nicks, as shown in Fig. 3, then adjust the tool rest to the required position to grind the bevel as noted in Fig. 4. Work the chisel back and forth squarely across the face of the wheel as indicated. When it is worked on the face of the wheel, the bevel will have a slight hollow, making it easy to hone to a perfect edge several times before regrinding again becomes necessary.

The bevel should be about 30 degrees, this being obtained by making the length of the bevel twice the thickness of the chisel. A 20-degree bevel can be used for soft wood, but in all cases where the tool is used on hardwood, an angle of about 30 degrees is preferred. After grinding, the chisel should be whetted on an oilstone with the bevel flat on the stone as shown in Fig. 5. Hold the chisel in the right hand and grasp the edges of the stone with the fingers of the left hand to keep it from slipping, or place the stone on a bench and block it so it cannot move.

Both hands will thus be free to use in whetting. Grasp the chisel in the right hand where the shoulder joins the socket, place

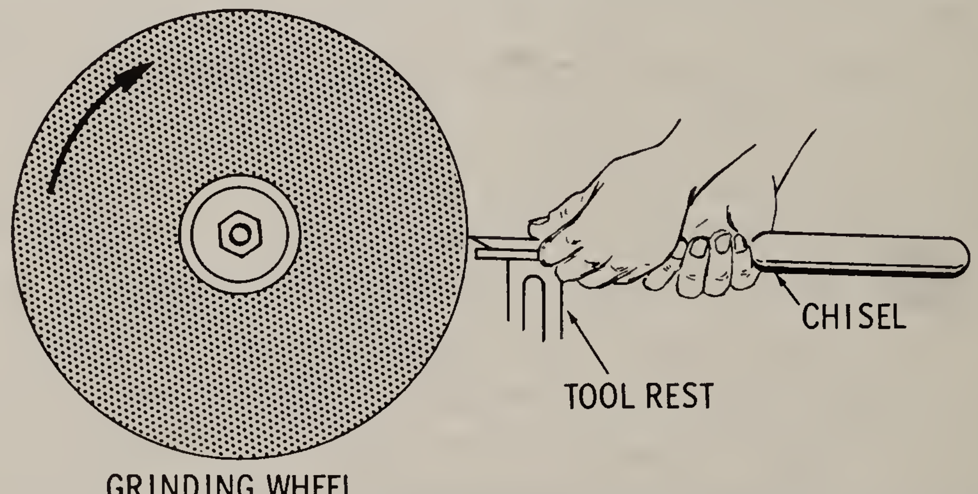


Fig. 3. Method used to remove nicks and irregularities from cutting edge of wood chisel prior to sharpening.

the middle and forefinger of the left hand on the blade near the cutting edge, and run the chisel back and forth on the stone, being careful to keep the original bevel. Never sharpen the chisel on the back or flat side—this should be perfectly flat. Remove the wire edge by a few strokes of the flat side along the stone.

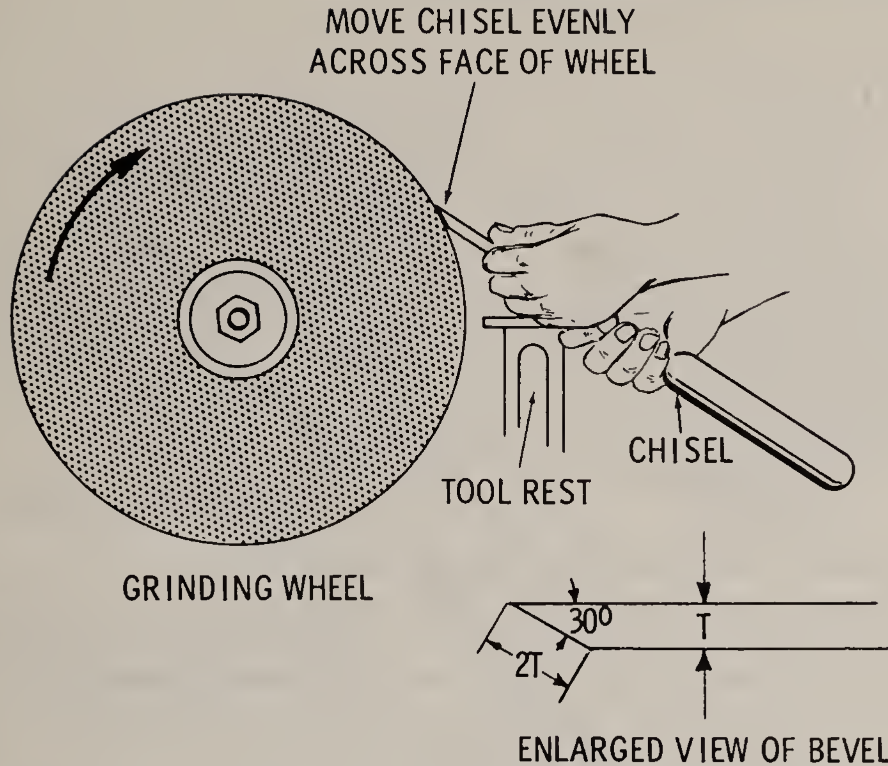


Fig. 4. Final grinding operation and approximate relationship between the bevel and thickness of chisel.

Fig. 5. Proper whetting practice. After whetting, the featheredge may be removed by a few strokes of the flat side of chisel along the oilstone as shown.

The sharpening stone should always be oiled, the purpose being to float the particles of metal so they will not become embedded in the stone. A thin oil or kerosene is satisfactory. When the honed bevel becomes too long through repeated whettings, the chisel should be reground.

How to Sharpen Plane Irons—Plane irons are sharpened in the same manner as wood chisels. In grinding, the cutting edge must be ground perfectly square; that is, the cutting edge must be at right angles to the side. Enough metal must be removed to take out any nicks in the cutting edge. To get the correct grinding angle (Fig. 7), make the bevel a little longer than twice the thickness of

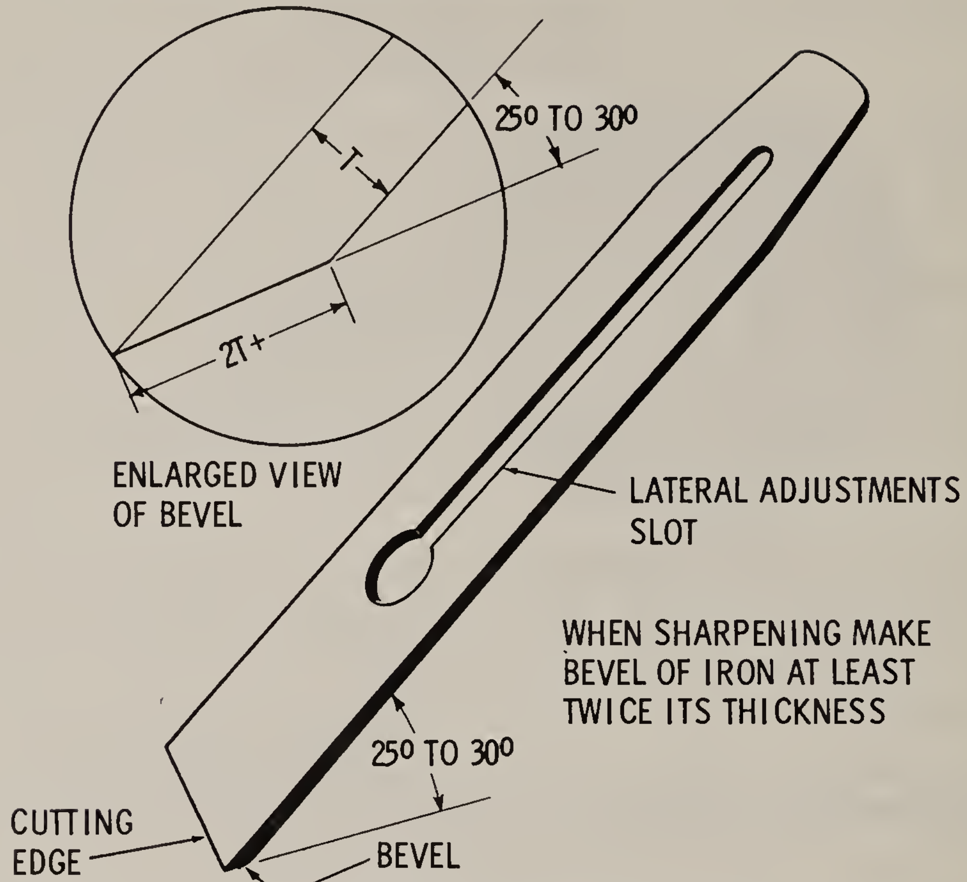


Fig. 6. Plane iron and approximate relationship between thickness and bevel of plane iron.

the iron. Plane irons should be ground straight across with a slight rounding at the corners.

After careful grinding, whet the plane iron on the oilstone to produce a sharp cutting edge. Hold the plane iron in the right

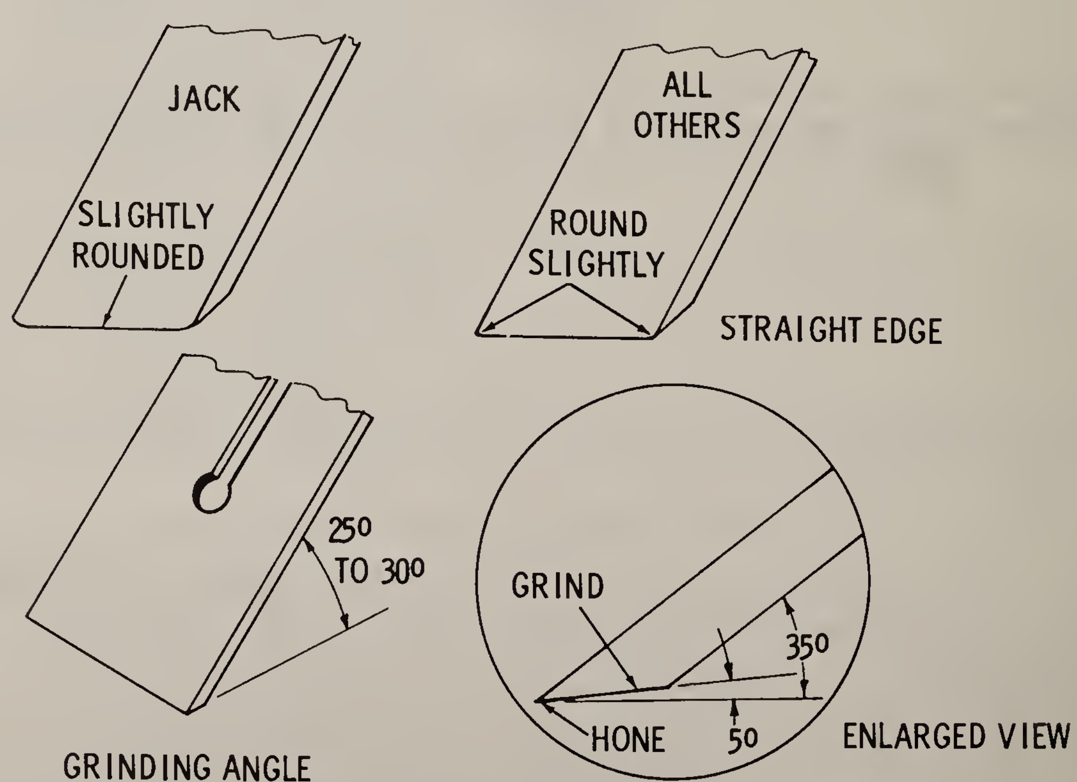


Fig. 7. Proper grinding and whetting angle for typical plane irons.

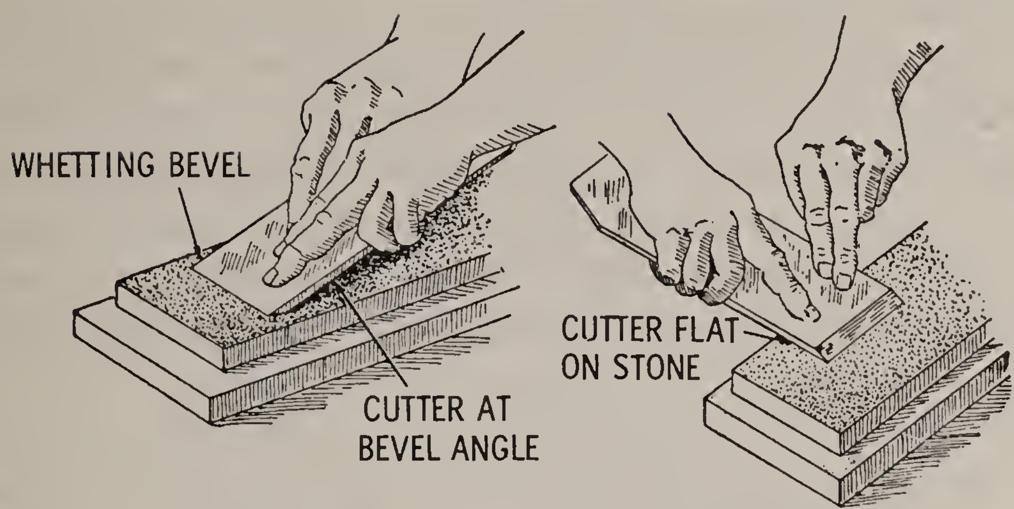


Fig. 8. Method of whetting plane iron on oilstone after grinding. Grasp the plane iron firmly in the right hand with palm downward, pressing down with left hand near cutting edge to give rubbing pressure. Rub to and fro nearly the length of the stone. Never use an undulating motion as this will produce a round edge necessitating frequent grinding. After whetting the bevel side, turn plane iron over and hold perfectly flat on the stone as noted and remove any wire edge by a few strokes of the plane iron.

hand with the left hand guiding it as shown in Fig. 8. Place the bevel on the oilstone with the back edge slightly raised. Move the plane iron back and forth. To keep the bevel straight, be sure that the hands move parallel to the stone so that the angle between the plane iron and the stone will stay the same throughout the stroke. Use enough oil to keep the surface of the stone moist.

In the case of a "double" plane iron, the plane-iron cap should have a fine edge, but not a cutting edge, and must be made to fit the face of the plane iron accurately, for if it does not, the plane will quickly choke with shavings because of the shavings driving between the plane iron and the plane-iron cap. This is im-

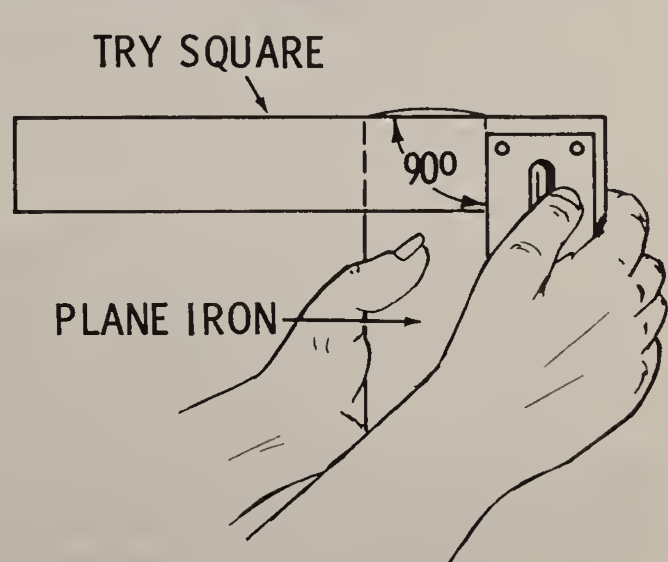


Fig. 9. Method of checking squareness of plane iron.

portant, and it should be noted that a very minute opening between the irons will let the shavings drive in and choke the plane.

Adjusting the Blade—After sharpening, the plane iron must be inserted in the plane and adjusted for proper cutting. Planes of modern make are provided with a lateral adjustment lever for adjusting the blade in a straight line, in addition to a setscrew for in and out movement of the iron. The "set" of the iron is the

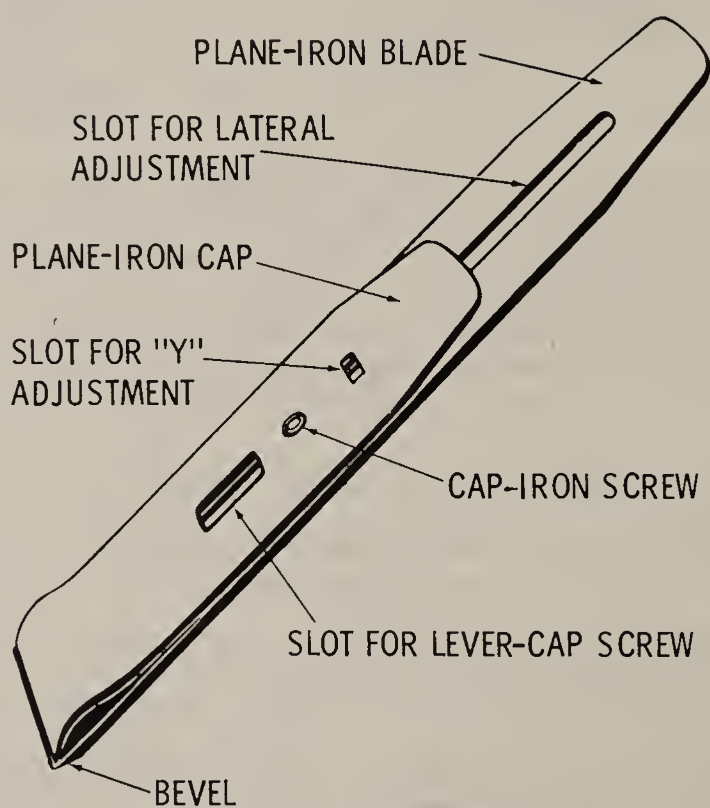


Fig. 10. Typical double plane iron.

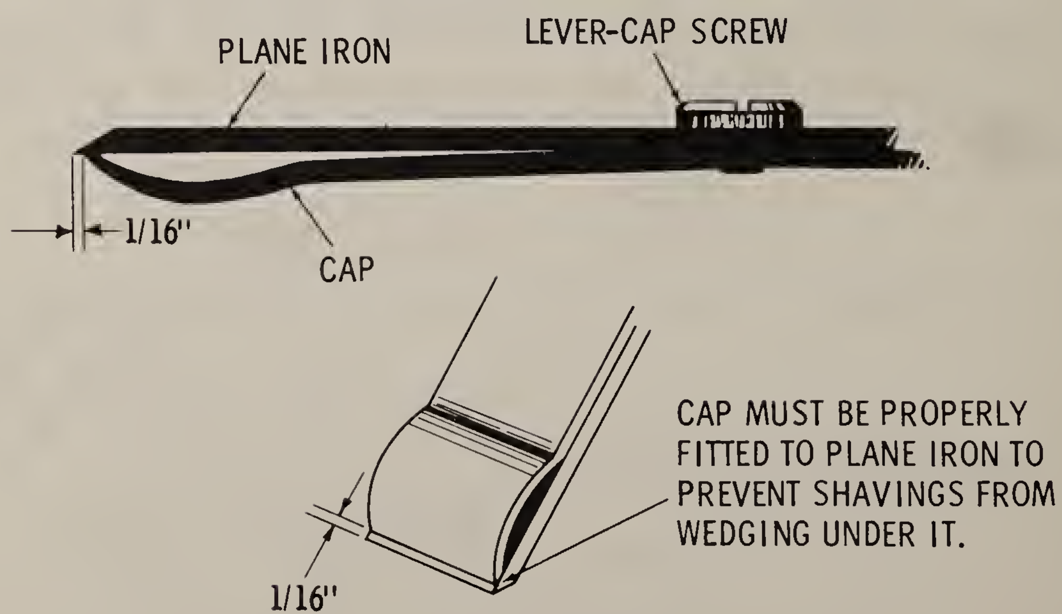


Fig. 11. Method of adjusting edge on plane iron with cap. For general work, the plane-iron cap should extend 1/16 inch back of the cutting edge of plane iron. On cross-grained woods and hardwood, the cap should be mounted as near the cutting edge as possible.

amount of plane-iron face exposed below the edge of the plane-iron cap, and the plane iron is said to be set coarse or fine according to the amount of plane iron exposed. The set regulates the thickness of the shavings and is varied in accordance with the nature and kind of wood being planed.

Although the amount of set is best found by practice, a rough estimate of the set, or projection, of the iron edge beneath the surface of the plane is approximately as follows: For soft wood, 3/16 in. for jack planes; 1/16 in. for jointer planes; and 1/32 in. for smooth planes. If the wood is hard or cross-grained, allow about one-half of the settings just given. The object of the plane-

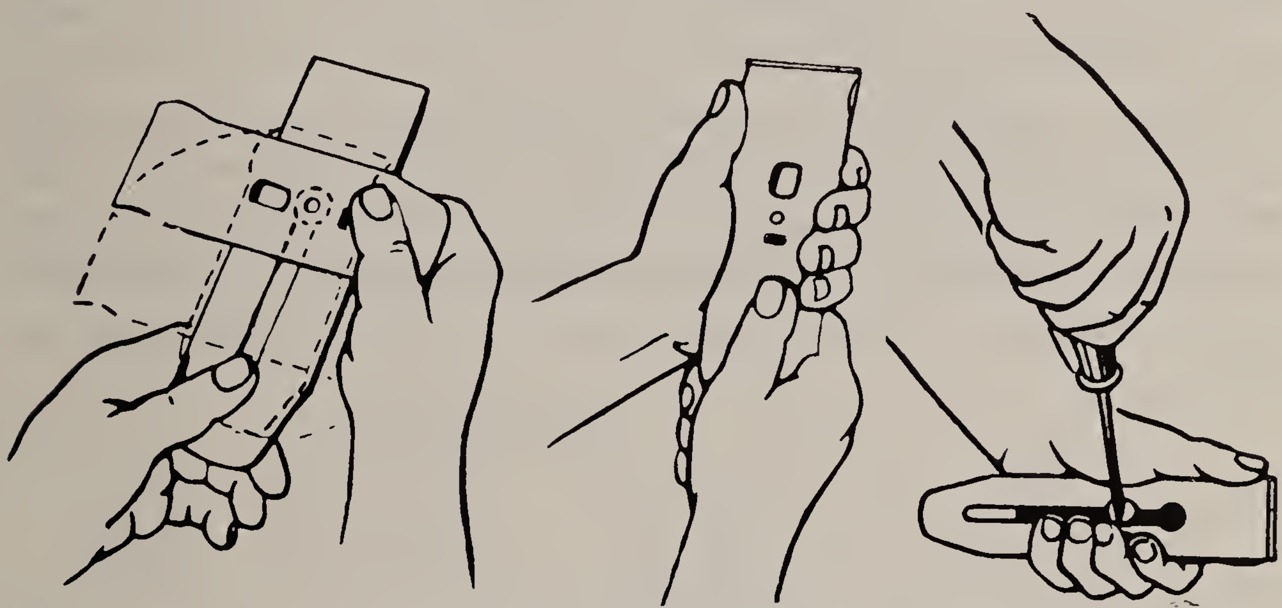


Fig. 12. Plane iron and plane-iron cap assembly. In the assembly process first lay the plane-iron cap on the flat side of the plane iron with screw in the slot, then turn the plane-iron cap around as illustrated. Before tightening the screw, be careful to adjust the plane-iron cap with plane iron.

iron cap in so-called double plane irons is to act as a shaving deflector—that is, the plane-iron cap breaks and curls the shavings. Together with the toe of the plane, it prevents the wood from splitting ahead of the cutting edge and in this manner produces a smooth surface. The plane-iron cap also serves to stiffen the plane iron.

To adjust the plane iron for evenness of the shaving, sight along the bottom of the plane and move the lateral adjusting lever to the right or left until the plane iron is parallel to the plane surface. A common mistake when adjusting the blade is to set the edge too far out. When planing, take off very thin, almost transparent shavings. This will give the best results and avoid gouging the work or clogging the throat of the plane with the shavings.

How to Sharpen Hatchets and Knives—The first step in restoring dull and nicked hatchet blades to their original shape and keenness is to grind the blade to remove nicks. The cutting edge is then ground to the bevel shown in Fig. 13. Frequent quenching is necessary during the grinding process to prevent loss of temper.

The cutting edge can be ground with a straight bevel if it will be used only for light work, otherwise the bevel must be convex to give support to the cutting edge. If the hatchet is a curved-edged tool, hold the tool stationary and sharpen it by moving the oilstone across the cutting edge with a circular motion. If the particular hatchet is a straight-edged tool, sharpen it by rubbing back and forth on the oilstone.

Knives—Small knives are never ground but can be sharpened by stroking them across an oiled stone with the back edge of the knife lifted slightly to produce the proper bevel. For cutting soft material, a long bevel is used; for heavier materials a short bevel is best. Always sharpen away from the edge as illustrated in Fig. 14.

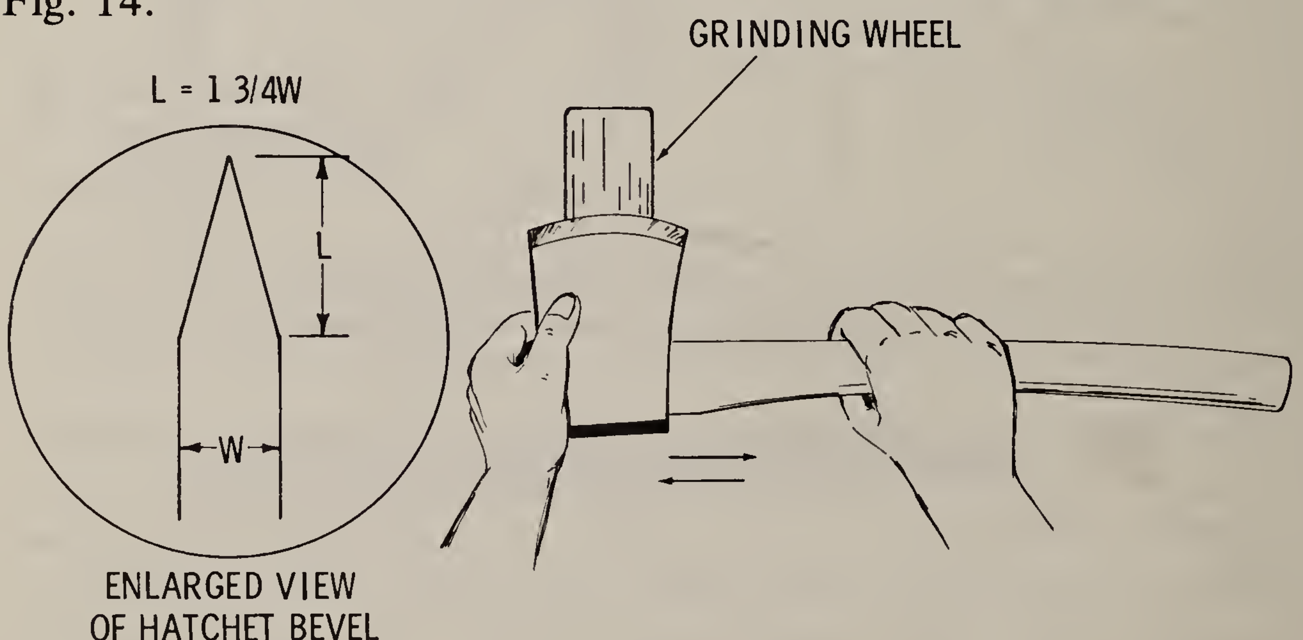


Fig. 13. Method of hatchet grinding. For best results the average hatchet should be ground so that the length of the bevel is approximately 1¾ times the thickness of the hatchet. Thus, for example, if the hatchet is ⅜ in. thick at the uppermost part of the beveled edge, the total length of the bevel would be 0.375 × 1.75 or ⅝ in. approximately.

Drawknives are ground with a single or double bevel and, in either case, the length of the bevel is approximately twice the width of the blade as in the case of chisels. First grind the blade square

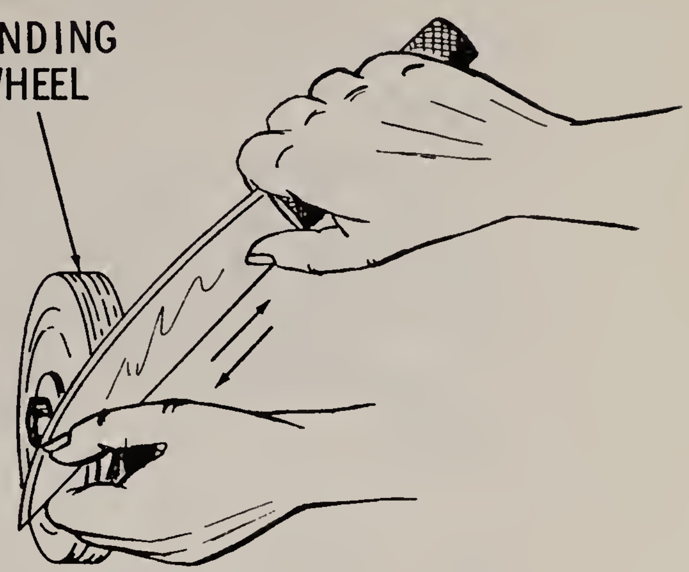


Fig. 14. Method of sharpening a knife on the grinding wheel.

to remove nicks, then place the blade on the grinder tool rest to obtain correct angle of bevel and move the entire knife from side to side, beveling the entire length of the blade. During the grinding operation, dip the blade in water frequently to preserve temper. If a double bevel is desired, turn the blade over and repeat the

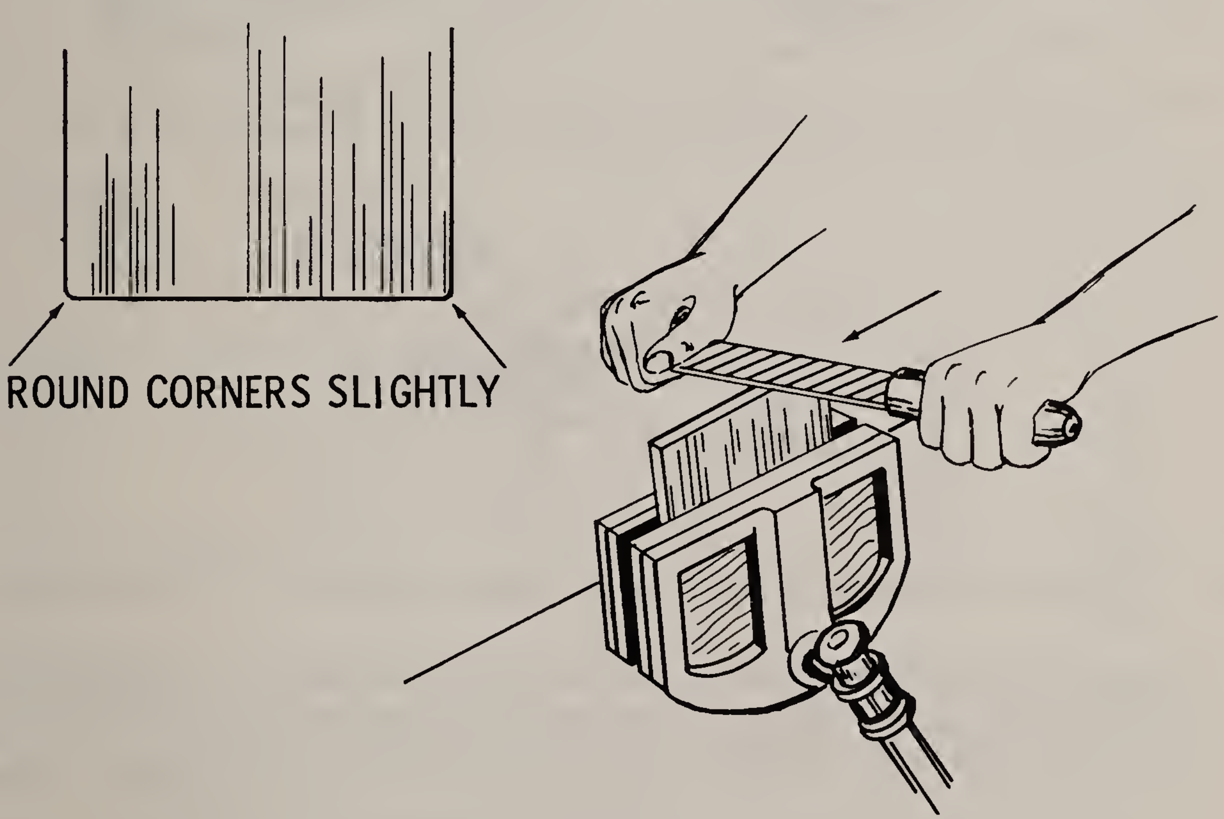


Fig. 15. First step in sharpening of a cabinet scraper.

process. Drawknives are whetted by laying them flat on their bevel on an oilstone and making circular motions the entire length of their blades. Remove wire edges when finished.

How to Sharpen Cabinet Scrapers—To sharpen an unmounted hand cabinet scraper proceed as follows:

Sharpening of Woodworking Tools

1. File the edges square and straight by draw filing with a smooth mill file and round the corners slightly as shown in Fig. 15.
2. Next, whet the edge as shown in Fig. 16, holding the blade square to the surface of the oilstone. Some woodworkers prefer to hold the scraper square to the edge of the oilstone.
3. Remove the burr by whetting the scraper flat on the oilstone as shown in Fig. 16. The edges should be very smooth and sharp.

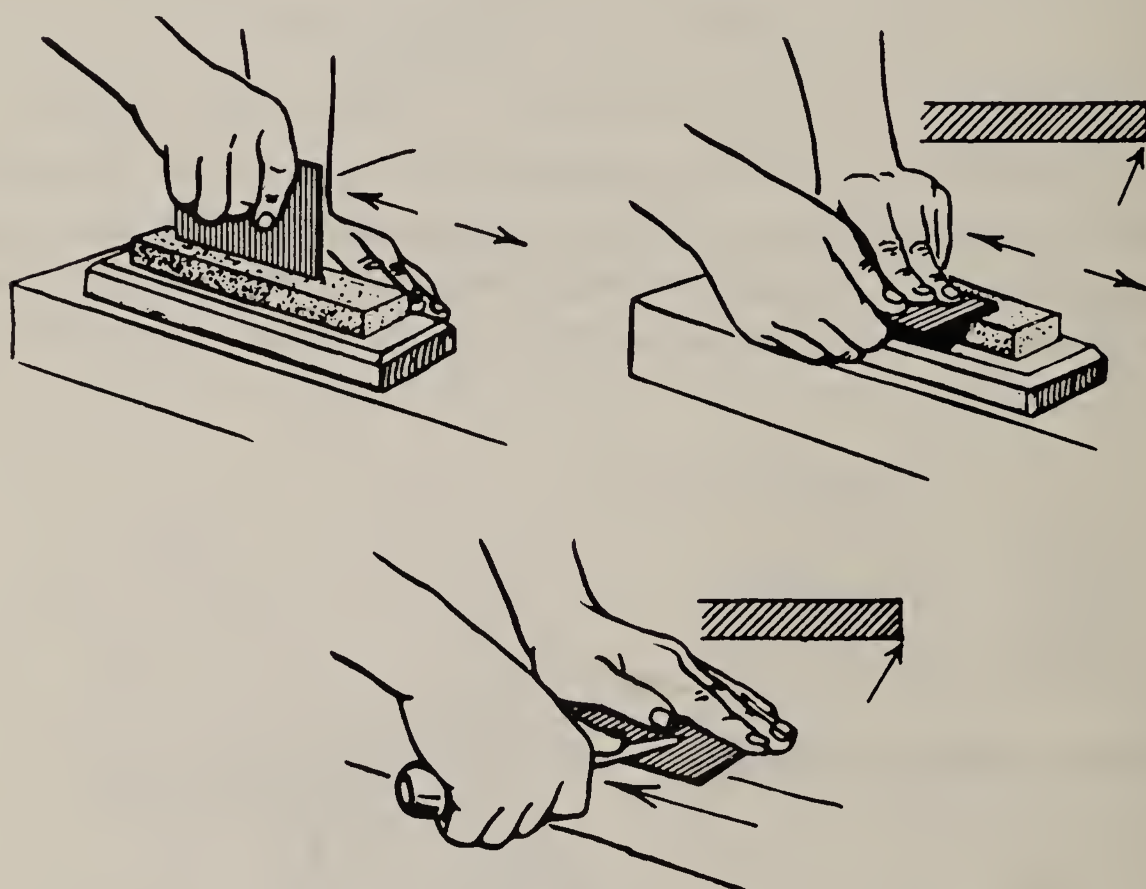


Fig. 16. Various intermediate steps used in sharpening of a cabinet scraper.

4. Draw the edge with three or four firm strokes of the burnisher held flat on the scraper as shown in Fig. 16.
5. Turn the edge with a few strokes of the burnisher. The scraper can be held in a vise or as shown in Fig. 17.
6. To turn the edge out, the burnisher is held at a 90-degree angle to the face of the blade for the first stroke. For each of the following strokes, tilt the burnisher slightly until at the last stroke it is held at an angle of about 85 degrees to the face of the blade as shown in Fig. 18. By following the foregoing instructions, the scraper will once more be a

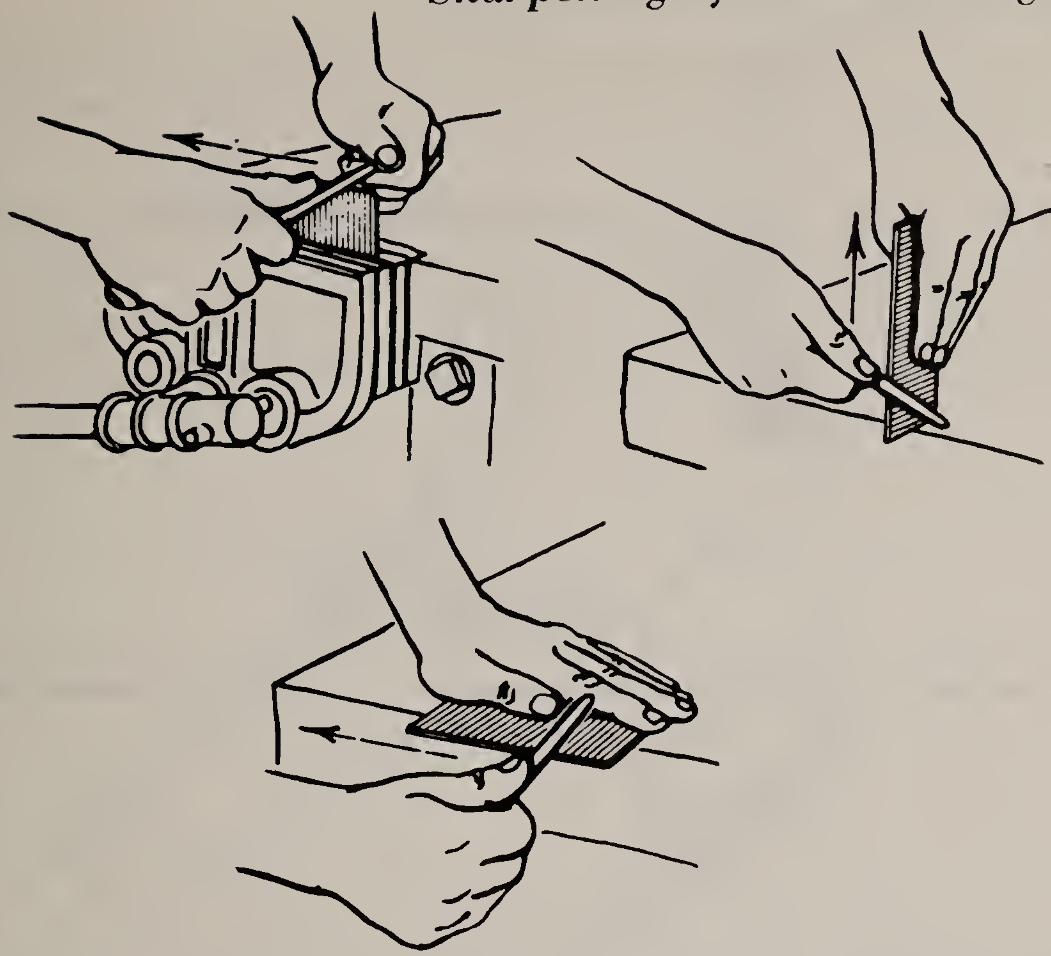


Fig. 17. Method used to turn the edge with a few strokes of the burnisher. The scraper may be held in any one of the three positions shown.

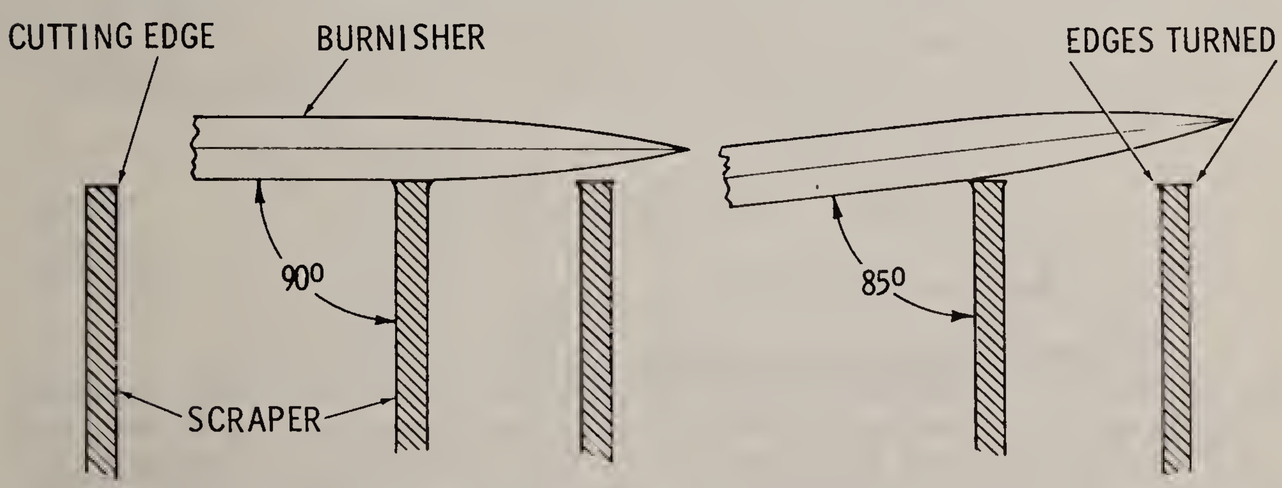


Fig. 18. Application of burnisher in turning the edge of the scraper after filing and honing. The edge of the scraper is usually turned in two or three strokes with burnisher at various angles, the finishing angle being about 85 degrees.

sharp-edged tool, with a hook edge that will quickly remove surplus wood in the form of shavings—not dust.

How to Regrind Screwdriver Tips—Screwdrivers, like putty knives, are not sharpened. When a screwdriver tip is worn out of shape, it should be ground so that the sides will be nearly parallel rather than chisel shaped. The tip is first ground off square;

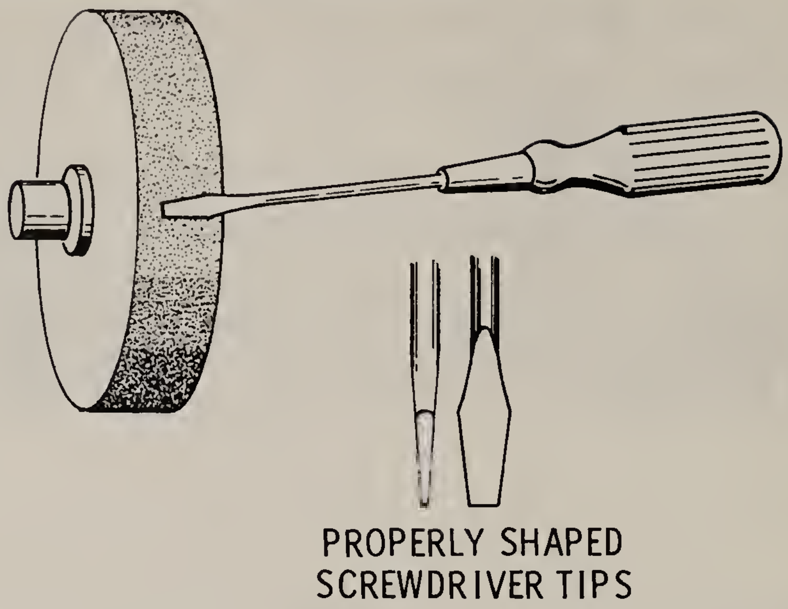


Fig. 19. Method of grinding worn screwdriver tips to bring them back to their original shape.

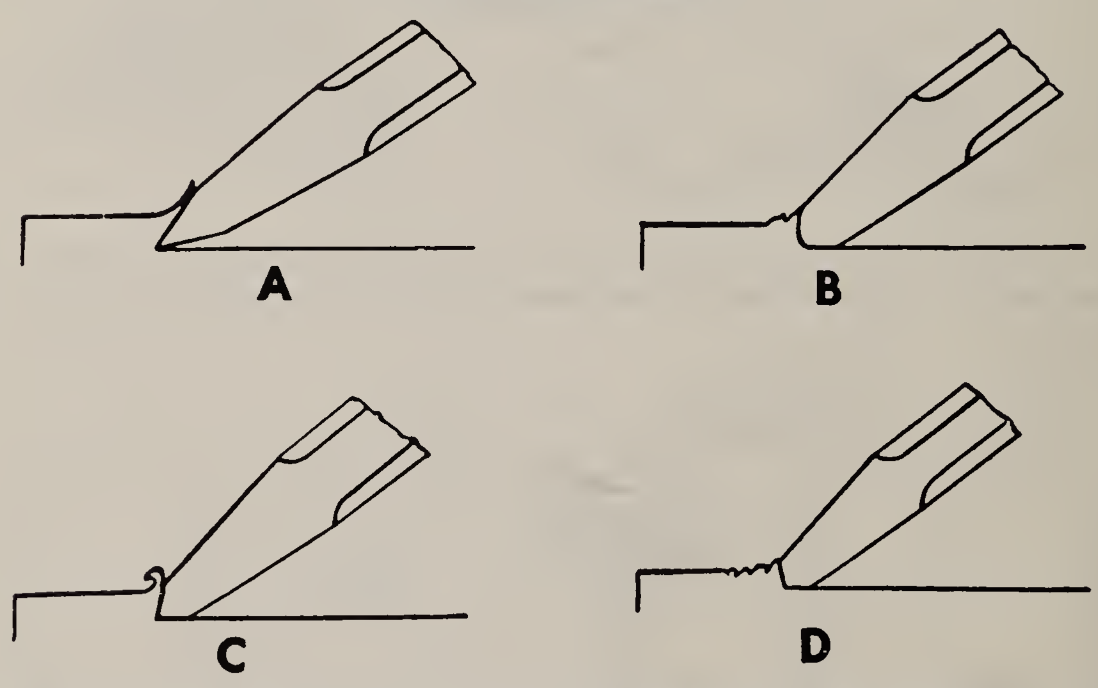


Fig. 20. Results of correct and incorrect sharpening of cold chisels. As noted in A, the angle at cutting edge is too small for general use; in B, the point is too rounded and dull for effective use. The correct angle at cutting edge is shown at C, whereas at D, the tool is dull due to incorrect sharpening.

then the sides are ground, holding the screwdriver as shown in Fig. 19, to produce nearly parallel sides. During the grinding operation, the tip must be dipped in water frequently to preserve temper.

How to Sharpen Cold Chisels—Like other cutting tools, chisels must be sharp to give satisfactory service. Cold chisels are ground or filed with a bevel on both sides forming an angle of about 65 degrees for average work. When sharpening a cold chisel, try to maintain the original angle of the cutting edge by grinding only a small amount at a time from each side. Hold the chisel

against the wheel with very little pressure to avoid overheating, and frequently dip the cutting end of the chisel in water to keep it cool.

If the cutting angle is ground too sharply, the chisel will not be safe to use; or if this angle exceeds 65 degrees, the tool will not cut properly. The results of correct and incorrect sharpening are shown in Fig. 20. Blows of the hammer will eventually cause the

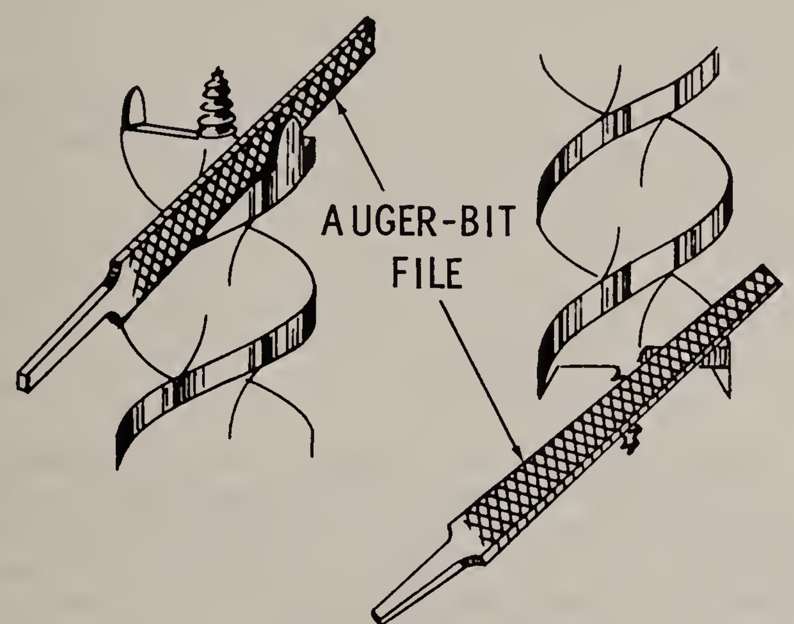


Fig. 21. Method of sharpening auger bits. As noted, the spurs are always filed on the side toward the shank to prevent losing clearance on the bottom. After sharpening remove the burr with a suitable oilstone.

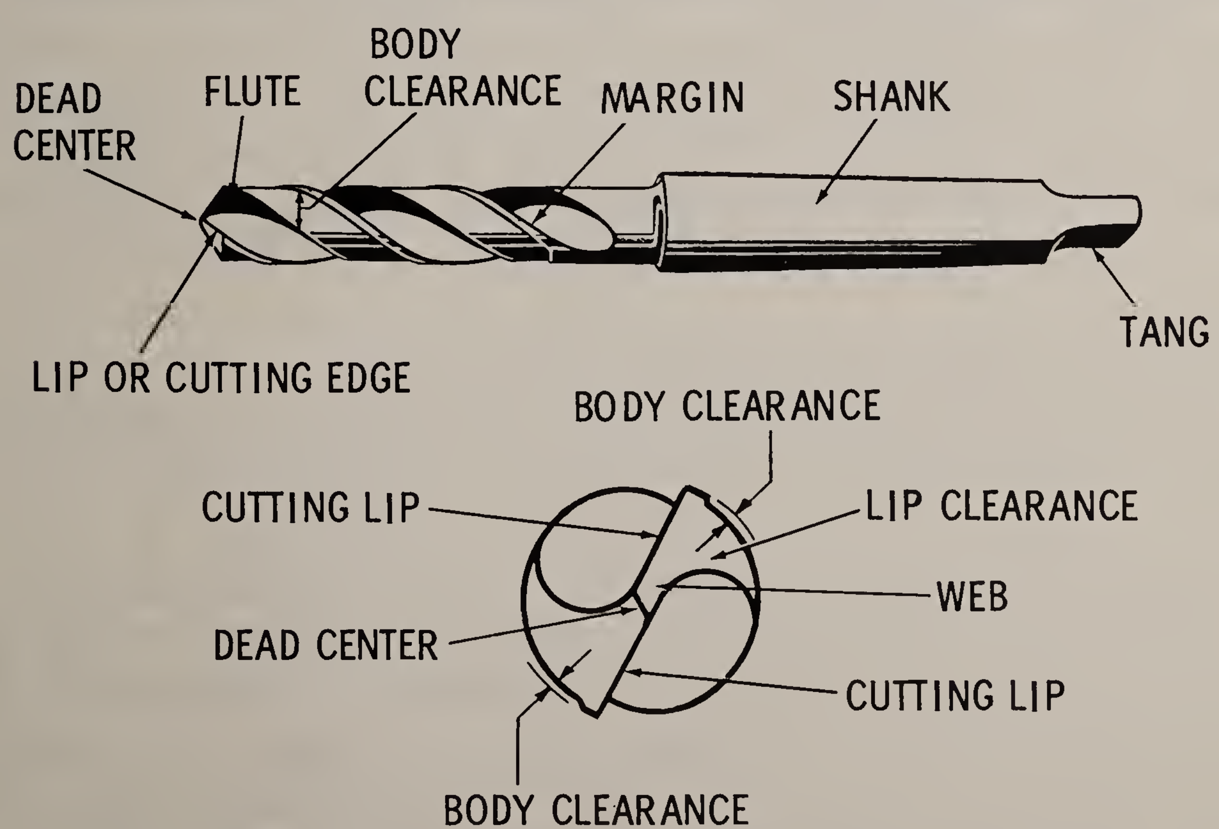


Fig. 22. Typical twist drill and enlarged view of point.

blunt end of the chisel to spread out until it resembles a mushroom. When this happens, grind the end back to its original shape. It is dangerous to use a cold chisel with a mushroomed head because pieces may fly off and cause injury.

How to Sharpen Auger Bits—Sharpening wood and auger bits is a rather simple operation which, if done correctly, will greatly assist in the boring of clean and smooth holes. To sharpen

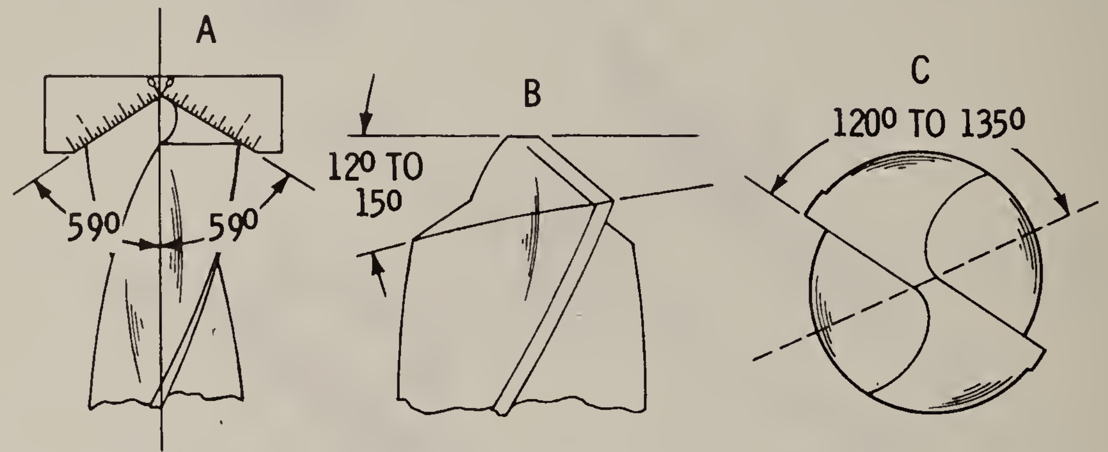


Fig. 23. Various angles required in a correctly sharpened twist drill. In the illustration; A, shows the point angle of 59 degrees which is satisfactory for general drilling of steel, iron and brass; B, gives the lip-clearance angle at the circumference of the drill which should be between 12 and 15 degrees; C, represents an end view of drill point showing proper angle between point and lip.

the spur, hold the auger bit in the left hand with the twist resting on the edge of the bench and with the auger-bit file held as shown Fig. 21. Turn the auger bit around until the spur to be sharpened comes uppermost. File the side spur next to the spur with an auger-bit file, carefully keeping the original bevel. File lightly until a fine burr shows on the outside. Carefully remove this burr by a light stroke with a file. For a keen cutting edge also whet with a slip-stone. Never sharpen the outside of a spur.

To sharpen the cutter, hold auger bit firmly in left hand with the worn point down on edge of bench and with the auger-bit file held as shown in Fig. 21. Sharpen the cutting edges on top to maintain the clearance on the under side. The cutting edges must be kept even, being careful to preserve the original bevel and to remove the burr or rough edge. Although it is rarely necessary or advisable to sharpen the feed screw, it may often be improved, if battered, by careful use of a three-cornered file of a size that fits the thread. A half-round file is best for the cutting edge and, with careful handling, may be used for the spur.

How to Sharpen Twist Drills—Twist drills should be correctly ground and sharpened, because if they are not in proper working condition, they will make holes that are rough or off size. The points involved in grinding are *dead center*, *point*, *head*, *lip-clearance angle, margin, body clearance* and *web*. Proper functioning of a twist drill involves all these parts.

The nomenclature of drill parts is as follows (Fig. 22): the dead center is the sharp chisel edge at the extreme tip end of the drill. It is formed by the intersection of the cone-shaped surfaces of the point and should always be in the exact center of the drill axis. The point of a drill is the entire cone-shaped surface at the cutting end and should not be confused with the dead center. The heel of a drill is the part of the point back of the lips or cutting edges.

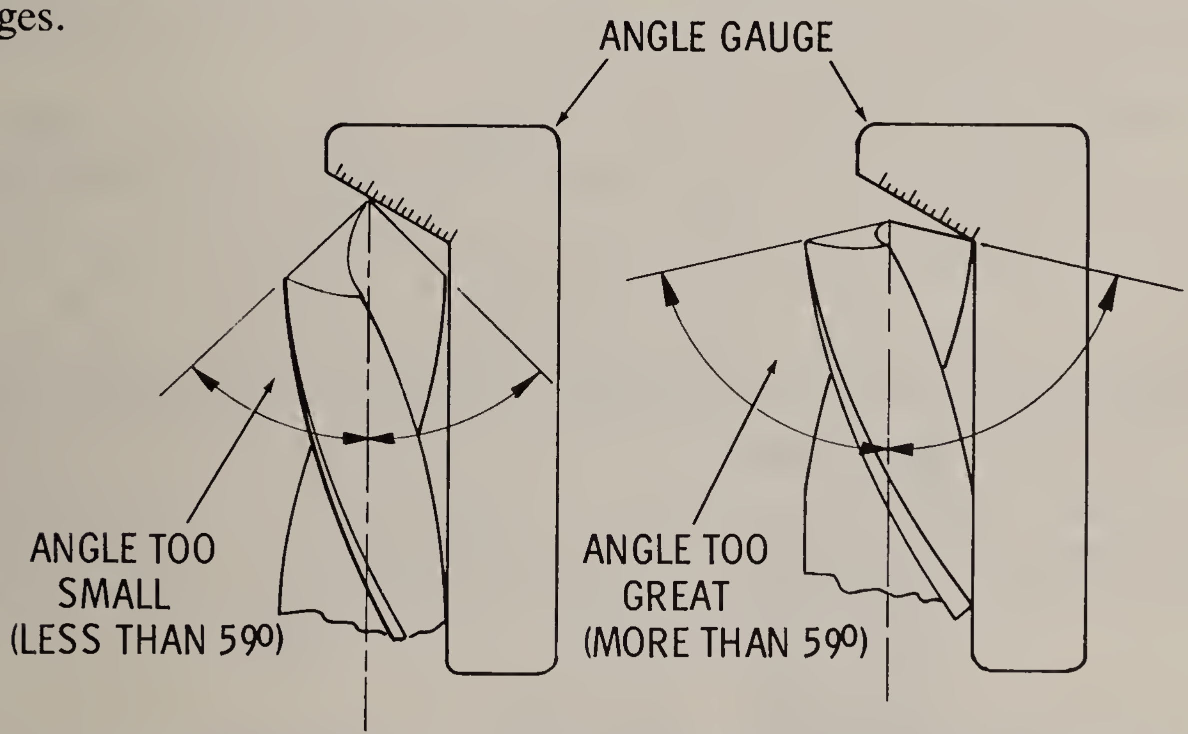


Fig. 24. Method of measuring point angle. This angle is easily checked with a drill gauge such as shown. Gauges of this sort are found in a wide variety of styles and are used to check the length of one lip against the other. A, shows a drill with the point angle too small, whereas, B, shows a twist drill with the point angle too great.

The lip-clearance angle is the angle at which the drill point is ground off just back of the lips. The margin is the narrow strip which extends the entire length of the flutes. It is the full diameter of the drill. Actually, the margin is part of a cylinder that is interrupted by the flutes.

The part of the drill back of the margin is of slightly smaller diameter than the margin. The difference is known as body clearance.

This clearance reduces the friction between the drill and the walls of the hole. The margin insures the hole being the right size. The web is the metal column which separates the flutes. It runs the entire length of the drill between the flutes, gradually increasing in thickness toward the shank.

Grinding the Lips or Cutting Edges—Both lips of a twist drill should be of the same length and ground to a 59-degree angle for work in aluminum, steel and cast iron as shown in Fig. 23. If the angle is more than 59 degrees, the point will be too flat to center properly. If, on the other hand, the angle is less than 59 degrees, the hole will be drilled less rapidly than it should be and more power will be required to drive the drill. If the point is on center, but the cutting edges are ground at different angles, the drill will bind on one side. Only one lip will do the work, and the hole will be larger than the drill.

Grinding the Lip-Clearance Angle—The heel of the drill—that is, the surface of the point back of the cutting lips—should be ground away from the cutting lips at an angle of from 12 to 15 degrees at the circumference of the drill, as shown in Fig. 23. Clearance is necessary on the whole surface of the point, and must increase as the center of the drill is approached. The reason for

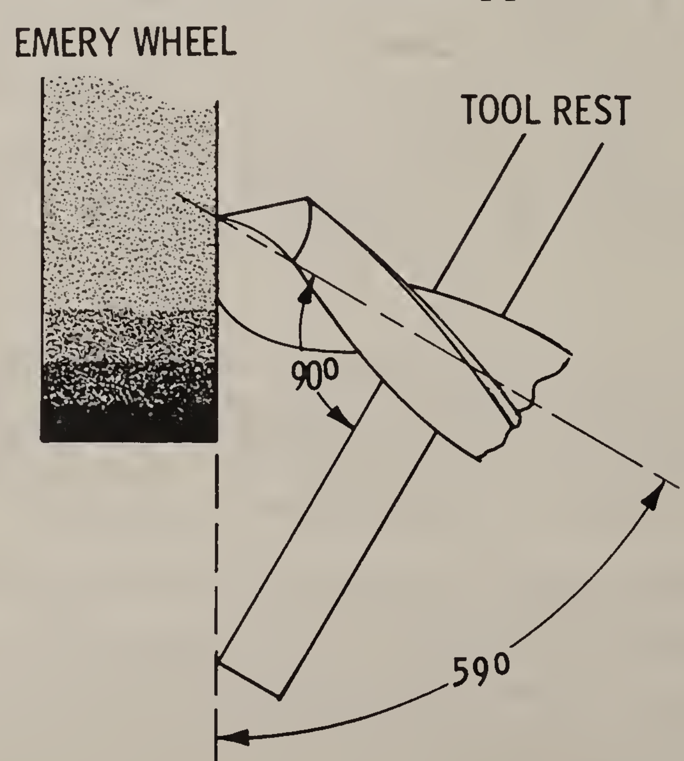


Fig. 25. Method of grinding to obtain correct point angle. If the axis of the drill is held at right angle to the tool rest, the point will be correctly sharpened at the required angle. The wheel should be a special wheel made for grinding on the side.

this is that the diameter at any point near the center is smaller than at the outer edge, yet every part of the point travels downward at the same rate. When this increased clearance is correctly ground on the drill, the angle of the dead center with the cutting lips will be from 120 to 135 degrees as shown in Fig. 23. When the lip-clearance angle is incorrect, the twist drill will "chatter."

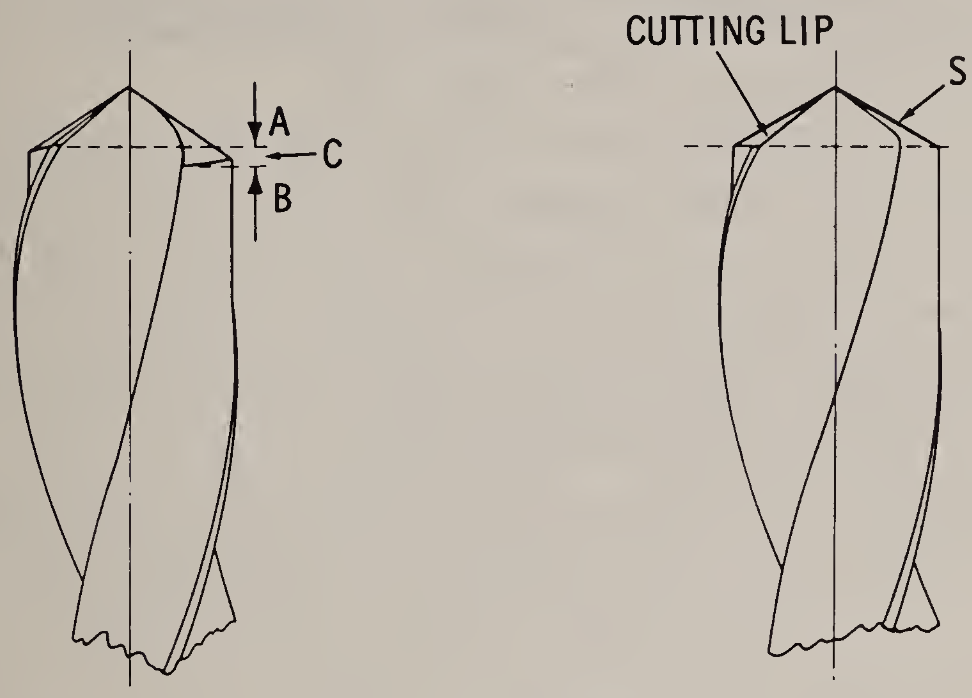


Fig. 26. Importance of proper lip clearance. A, shows a drill with proper lip clearance, while, B, shows a drill with no lip clearance. Heel line, B, must be lower than the cutting-lip line, A, for proper functioning of drill. It is the distance, C, that measures the amount of lip clearance. When the cutting lip and heel, S, are in the same plane, the drill is without lip clearance and will not cut. For proper lip clearance, the heel should be ground away or backed off until the angle of the point at outer circumference of drill is from 12 to 15 degrees.

Fig. 27. Common mistakes in drill grinding. When unequal angles or lips causes drill to wobble, oversize holes result. In the figure, A, represents a drill with lips of unequal angles and unequal lengths and, as a result, the drill point actually travels around the center of the hole; in B, the lips are of unequal angles and the right lip only is active in cutting; C, shows a drill with lips of unequal angles and unequal lengths which results in excessive wear on right lip.

Keeping the point angle and lip clearance in mind, it is comparatively simple to grind a drill with good results. It would be well, however, to make use of an angle-gauge block such as shown in Fig. 24, particularly at the outset, because the block will greatly assist the beginner in obtaining the correct angles. With the drill held in the position shown in Fig. 25, the proper point angle (59°) will be obtained. From this starting position, the drill is rotated about one-sixth of a full turn, at the same time moving to a position parallel with the penciled guide lines.

Each lip is treated in turn, checking with the drill gauge to see that both are of exactly the same length. The proper swing when dropping the end to give the proper lip clearance is best acquired by swinging a properly ground drill against the wheel, keeping the ground surface in contact with the wheel and observing the movements required to produce this surface.

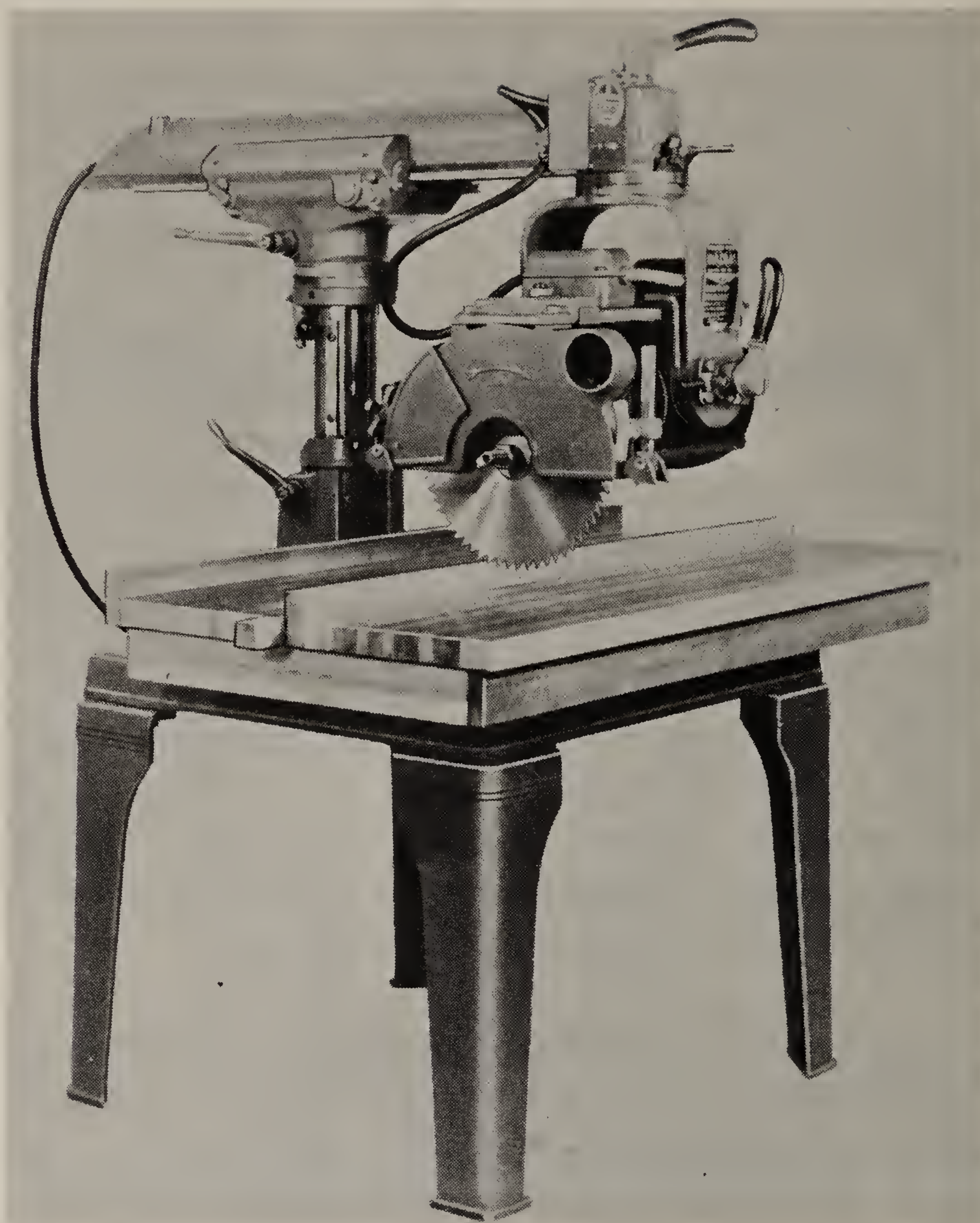
CHAPTER 9

Power-Tool Selection

The proper selection of power tools for the average home workshop is not a very difficult problem because of the great abundance of power tools now available. Depending upon the available space, floor area, individual requirements, and cost involved, selection can be made from the following three classes:

1. Multipurpose, single-unit power tools, which may be installed advantageously in the small home workshop where space is at a premium.
2. Single-purpose power tools equipped with individual motors. These have the advantage of being instantly available for each operation.
3. Single-purpose power tools equipped with only one motor. This type of machinery gives the user the advantage of individual units, but prevents their instant use, because the motor will have to be moved about from one unit to another as conditions require. It does, however, eliminate the expense of having a separate motor for each tool.

Multipurpose, Single-Unit Power Tools—There are several different types in this classification, each with certain basic characteristics. All have a single motor, and all occupy a limited amount of floor area. One well-known unit, for example, combines a circular saw, jointer, sander, and drill press in a single unit. Another unit is a radial-arm saw to which various attachments can



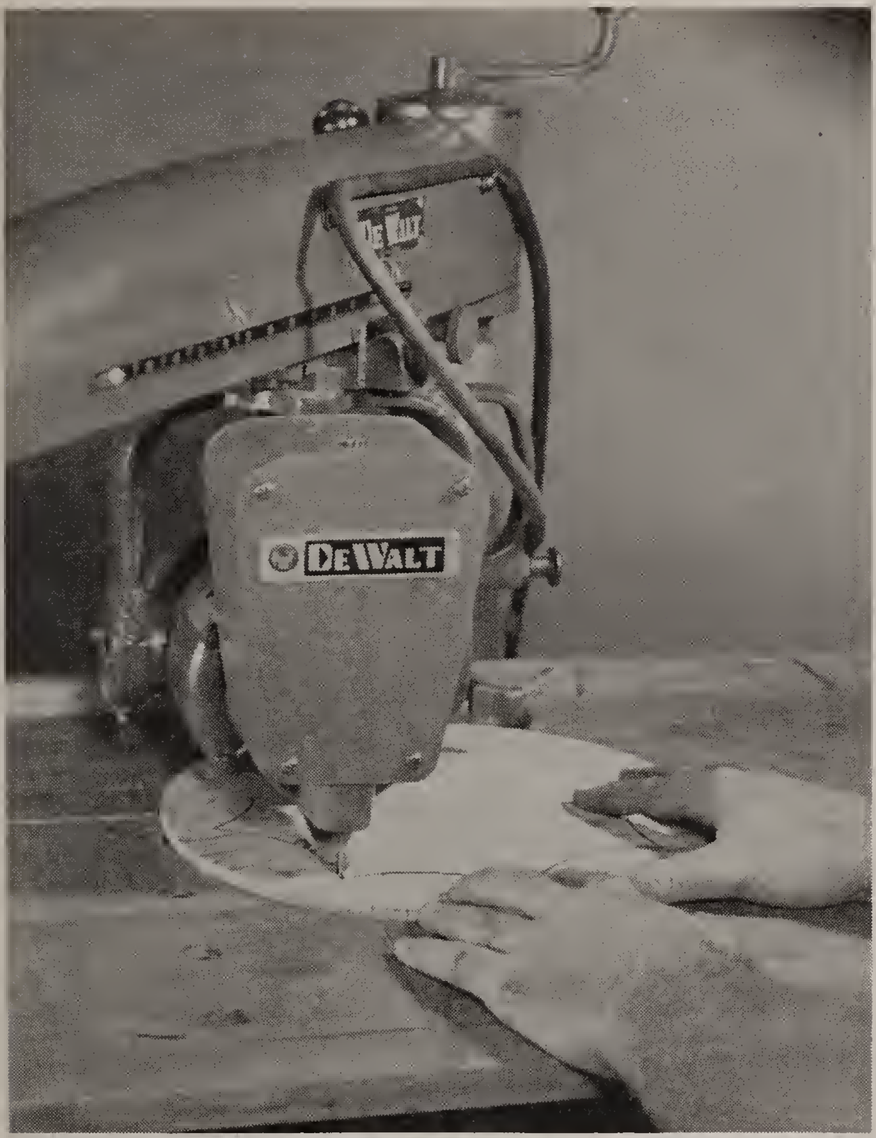
Courtesy American Machine & Foundry Co., Inc.

Fig. 1. The radial-arm circular saw. This saw represents a typical multi-purpose tool in that it will do five or six different types of operations by means of special accessories fitted to the motor shaft. The advantages of a power tool of this type are economy of space and the fact that it can do drilling, sanding, routing, planing and mortising, as well as drive many other tools in the shop.

be connected, converting it into a lathe, drill press, sander, shaper, router, grinder, jointer, or buffer.

It should be noted, however, that while these complete and compact power plants fit into a relatively small space and perform the work of many individual machines, there is always a time loss associated with converting the machine from one duty to another.

Although the foregoing may not be a major objectionable feature for the average home workshop, it will be a definite dis-



Courtesy American Machine & Foundry Co., Inc.

Fig. 2. Radial-arm saw with saber-saw attachment. The sturdy, enclosed, "Scotch-yoke" mechanism converts the rotary motion of the motor shaft into the reciprocating movement of the saber-saw blade.

advantage for the production worker who must adhere to a set time schedule.

Single-Purpose Power Tools—In every case where production is essential there is no substitute for the single-purpose power tool. Many home workshop owners prefer to add single-purpose tools on the installment plan basis; that is, the workshop is laid out and planned in such a manner that when the need arises for an additional power tool, it will be installed in its assigned place, and the projected workshop in time will be fully equipped.

The foregoing method of building a power-tool workshop, however, requires a great deal of knowledge as to future requirements, and the average operator will usually find certain parts of the equipment either unsatisfactory or poorly placed by the time the

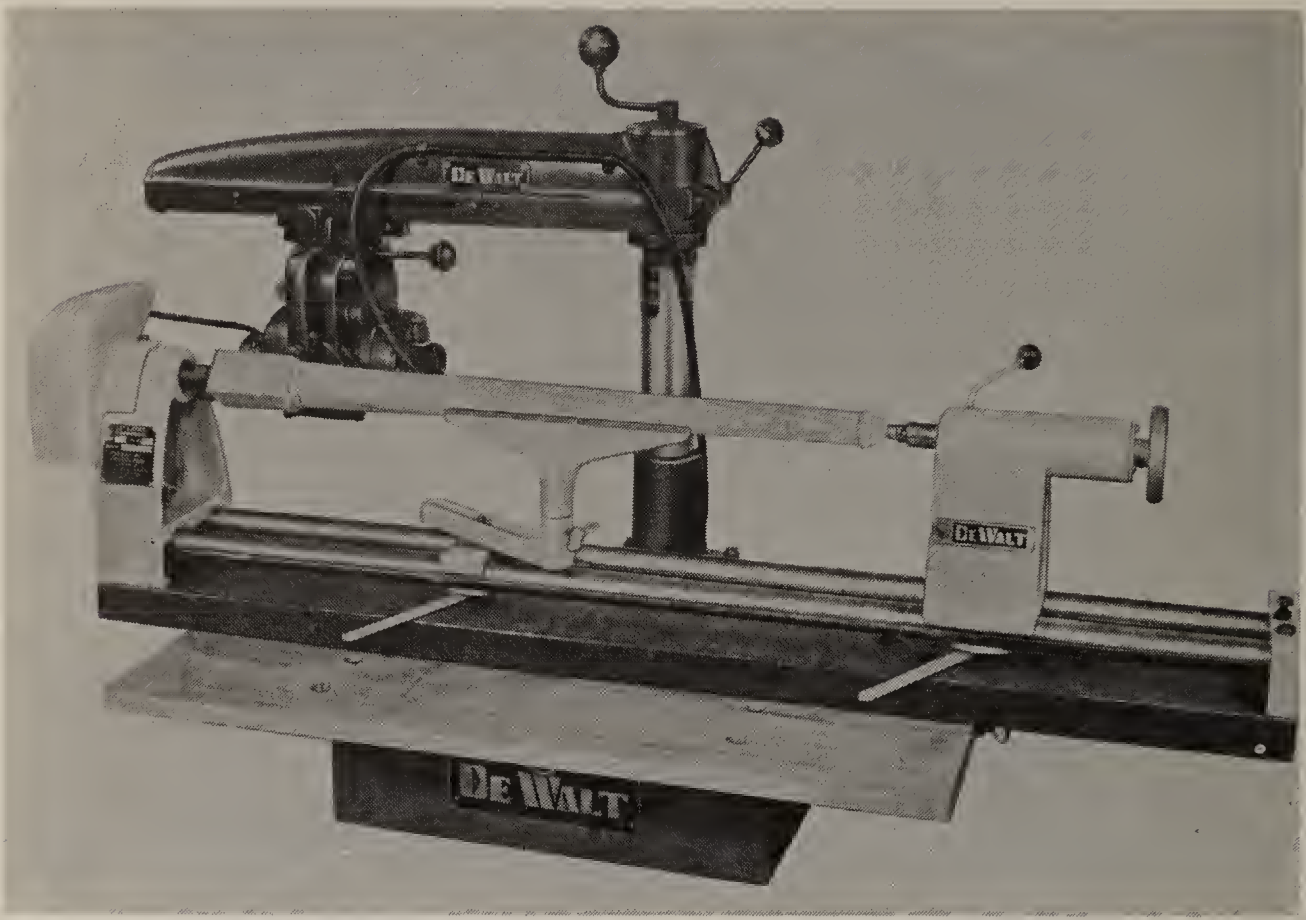


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Fig. 3. Radial-arm saw with woodturning lathe attachment. Substitution of a pulley for the standard blade and guard converts the basic machine to a power source for a woodturning lathe.

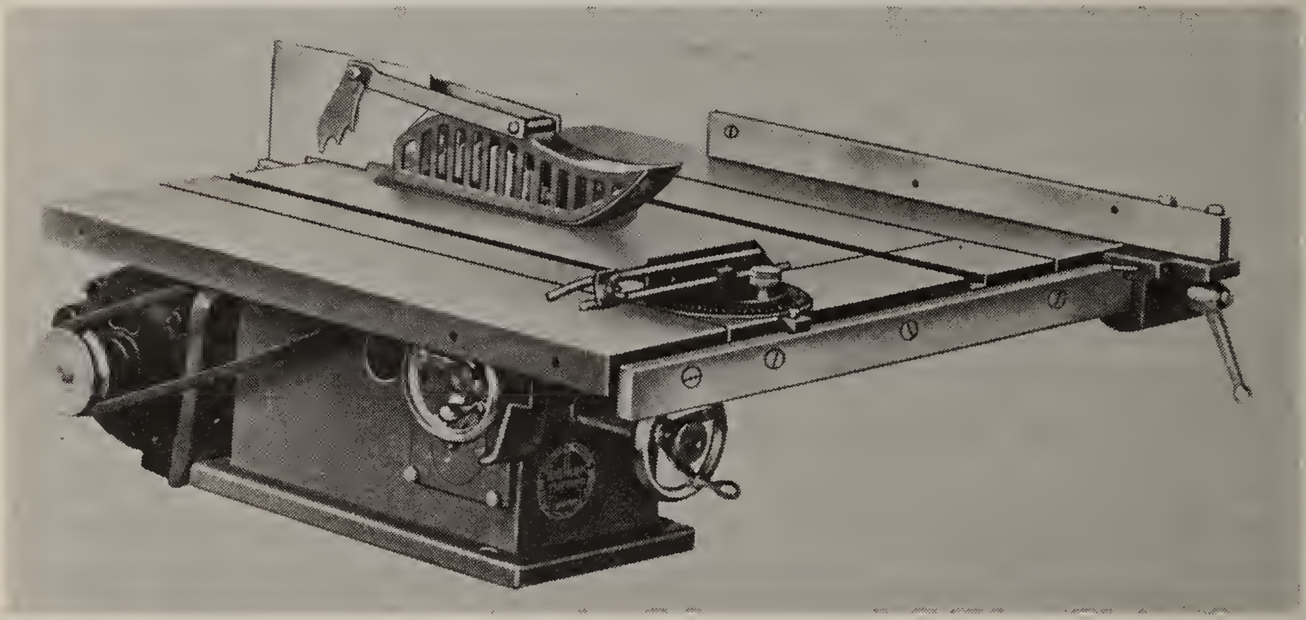
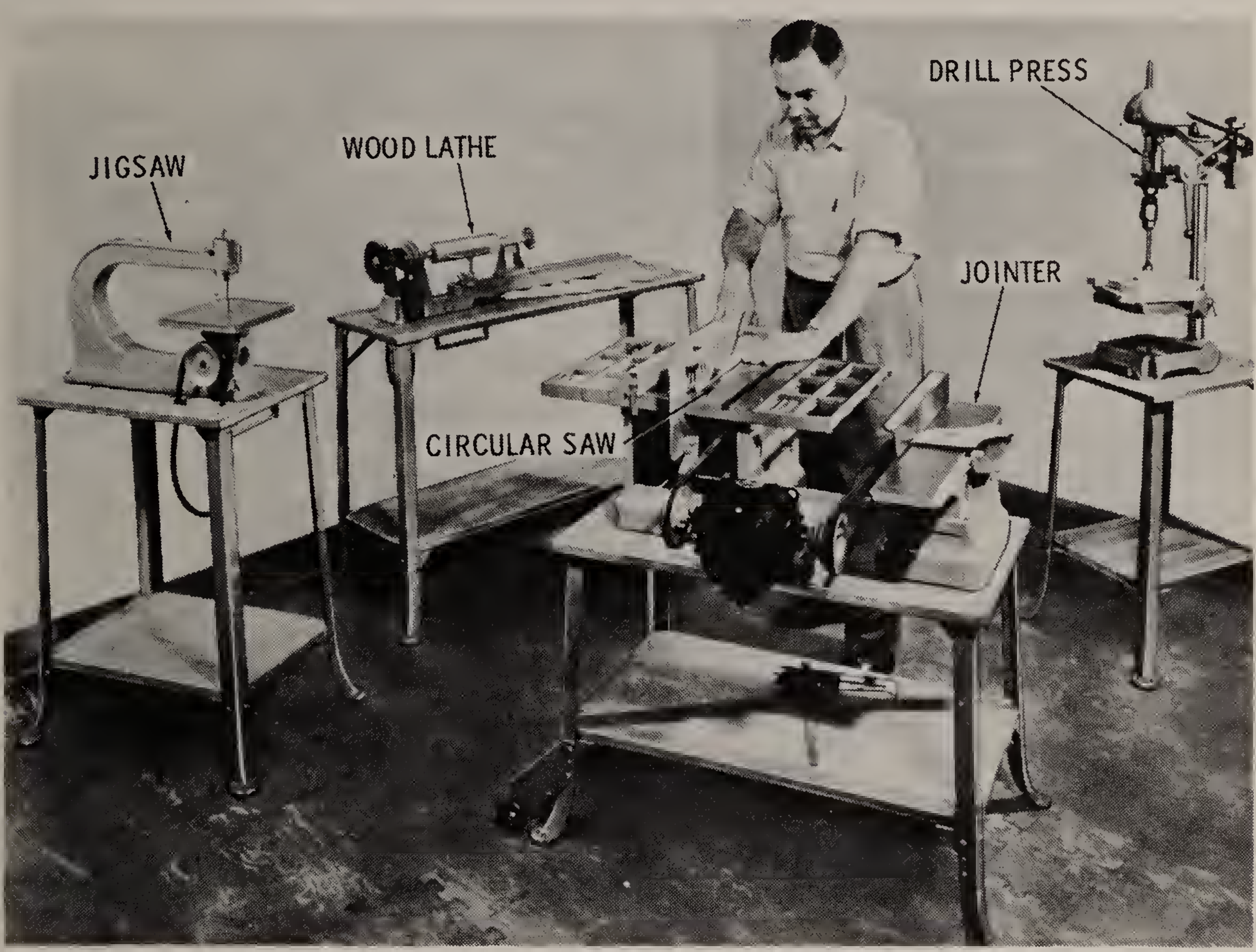


Fig. 4. Typical single-purpose power tool consisting of tilting-table circular saw. In the planning of a workshop of single-purpose power tools, the tools required in order of importance are: 1, circular saw; 2, drill press; 3, band saw; 4, jointer; 5, jigsaw; 6, woodturning lathe. Although the first choice should be a saw, a great many woodworkers prefer a band saw or a jigsaw to a circular saw as first choice; second choice, a drill press; third, a circular saw; fourth, a woodturning lathe, etc.

workshop is complete, unless great care is taken in planning each and every detail.

Single-Purpose Power Tools with Removable Motor—A power-tool workshop having one motor serving several single-purpose tools may be erected if the floor area permits. In an arrangement of this sort, special mounting brackets on the motor facilitate shifting it from one tool to another, but this obviously prevents the use of more than one tool at a time. Although this method will result in a considerable saving in motor cost, the apparent saving must be balanced against time wasted in refitting the motor when it is moved from one tool to another.



Courtesy Duro Metal Products Co.

Fig. 5. Single-purpose power tools with detachable motor. The motor, as presently located, will drive either the circular saw or the jointer. After disconnecting the motor from its source, it is a very simple matter to shift the motor from one tool to another as conditions require.

In summing up, the important factors to be considered when planning a workshop are:

1. The amount of space available.

2. The type and quantity of work.
3. The cost of power tools to be acquired.

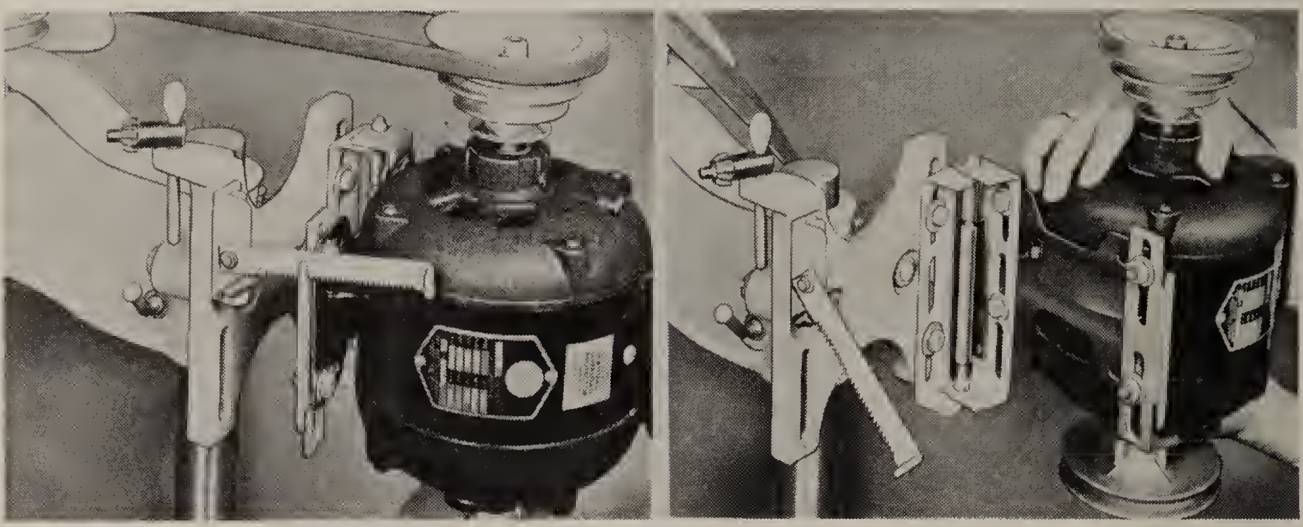


Fig. 6. Attachment of motor to drill press. To remove motor, merely lift belt-tension ratchet to release position and slip V-belt off pulley. Then grasp motor in right hand with fingers extended to safety catch spring release for removal of motor from the tool.

Although the various classes of power tools may differ considerably, depending upon the particular manufacturer, all power tools of standard make are now so well constructed and designed that it would be almost impossible to make a mistake in selection of power tools.

CIRCULAR SAW

The circular saw is one of the most popular machines in any woodworking shop or plant. Plants of any size usually have one or more power saws used exclusively for ripping and one or more for crosscutting. Beveling and mitering can be done with circular saws of the tilting-arbor type, while grooving and dadoing can also be done by means of special cutters.

Circular saws are made in a large variety of types and sizes, among which are the *universal* and *variety* saw. The universal type is equipped with two arbors to permit mounting of both ripsaw and crosscut blades, either of which is brought into use by simply turning a handwheel controlling the position of the arbor. The variety saw employs a single arbor and can be fitted with mortising and boring attachments.

The main structural features of either machine are similar, however, and include the arbor, saw blades, table, ripping fence, crosscutting and mitering fence or gauge, and a substantial base. In recent years, circular saws mounted on a radial arm above the work have come into wide use. These are usually equipped for variable angle cutting and can also be used for dadoing or other operations with special attachments.

Construction—The circular saw (Fig. 7) consists generally of a cast-iron base or frame on which a table is mounted and an arbor or shaft which carries the saw blade or other cutter. The arbor or shaft revolves in two bearings bolted to the frame. It is driven by a belt which passes over a pulley on the shaft.

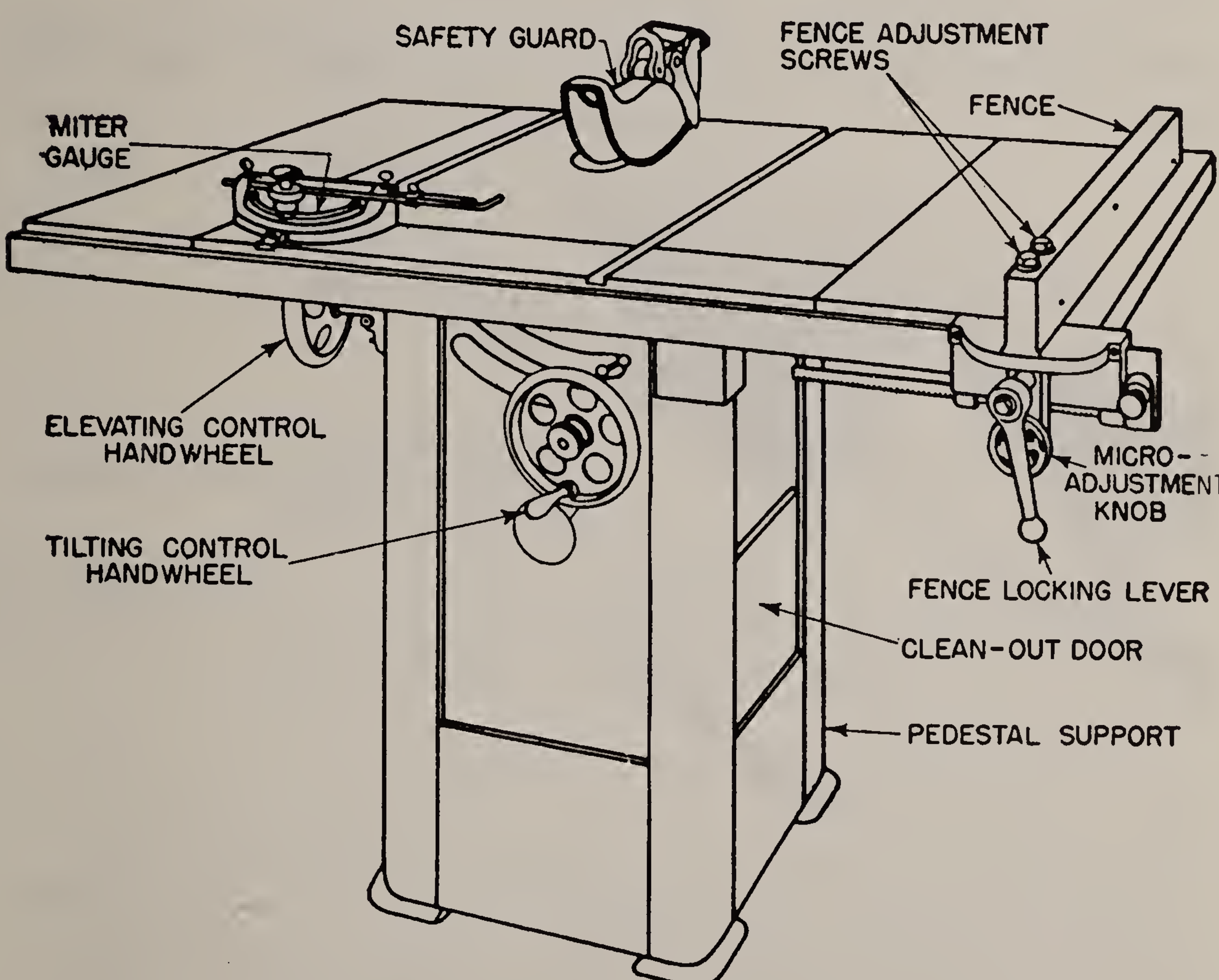


Fig. 7. Typical 10-inch, tilting-arbor saw. A circular saw of this type has a capacity of cuts 3⅛ inch deep; 2⅛ inch at a 45-degree angle. Dado head cuts 1⅛ inch deep. The drive is by means of a 3,450 rpm, self-contained electric motor, transferring power to the saw by means of a triple V-belt. The speed of the saw is 3,800 rpm. It is equipped with a cast-iron table, having both front and side extensions, in addition to safety guard, fence and miter gauge. By means of an easily accessible handwheel, the entire arbor and drive unit may be tilted to any desired angle for angle cutting.

In the conventional design, the saw table can be tilted to an angle of 45 degrees, whereas on the tilting-arbor type, the table is fixed in a stationary level position, tilt positions being obtained by tilting the saw blade. This latter design not only is of great convenience to the operator, but also supplies a safety factor since he does not have to work in an awkward position.

When wood is cut on a circular saw, it must be firmly held against a metal guide or fence set at a desired distance from the saw blade. When the fence is used as a guide for cutting boards lengthwise, the operation is known as *ripping*. Most saw tables are equipped with two slots or grooves to accommodate a miter gauge, which is used as a guide when sawing across a board, an operation known as *crosscutting*.

Ripping Operation—One of the most useful operations of the circular saw is that of ripping stock to its required width. This operation is generally accomplished as follows:

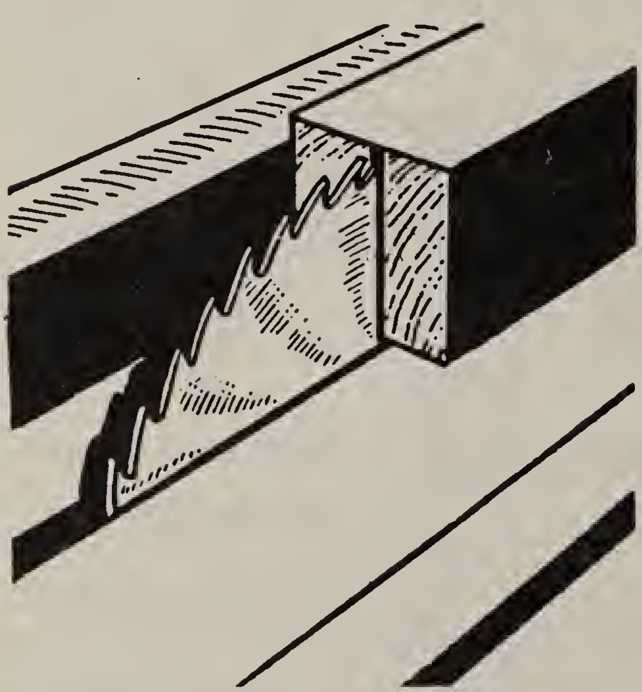


Fig. 8. Ripping operation on square stock.

1. The fence is set to the graduated scale at the front of the table to cut the required width.
2. The saw blade is adjusted (raised or lowered) to project approximately ¼ inch above the stock to be ripped.
3. The splitter and saw guard are positioned to insure safe operation.
4. The operation is started by holding the work close to the fence and pushing it toward the rotating saw blade with a

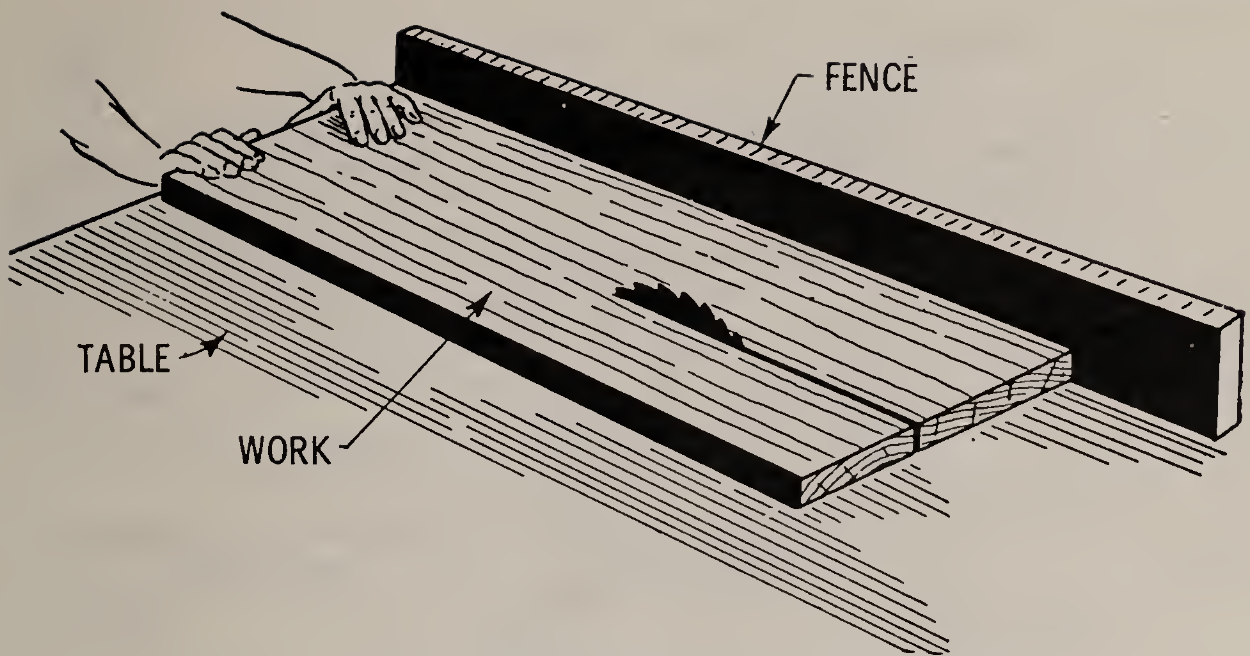


Fig. 9. Typical ripping operation on wide stock.

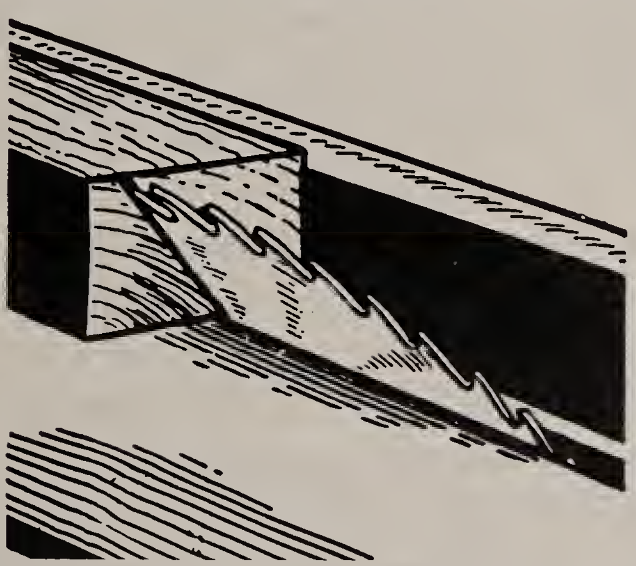


Fig. 10. Bevel ripping on tilting-arbor saw. Bevel cuts on the tilting-table saw are made in the same manner as on tilting-arbor saw. Here the table is tilted and set at the required angle by means of a graduated scale located beside the tilting mechanism handwheel.

firm, even motion. A smooth, uniform speed of feed should be used, avoiding jerky movements and jamming the work through too quickly. The operator should not stand directly behind the saw blade, but should take a position a little to either side and hold the stock near its ends so that one hand will pass to the right side and the other to the left side of the saw blade.

Crosscutting Operation—Square crosscutting on the circular saw is performed by placing the work against the miter gauge and advancing both the gauge and the work toward the rotating saw

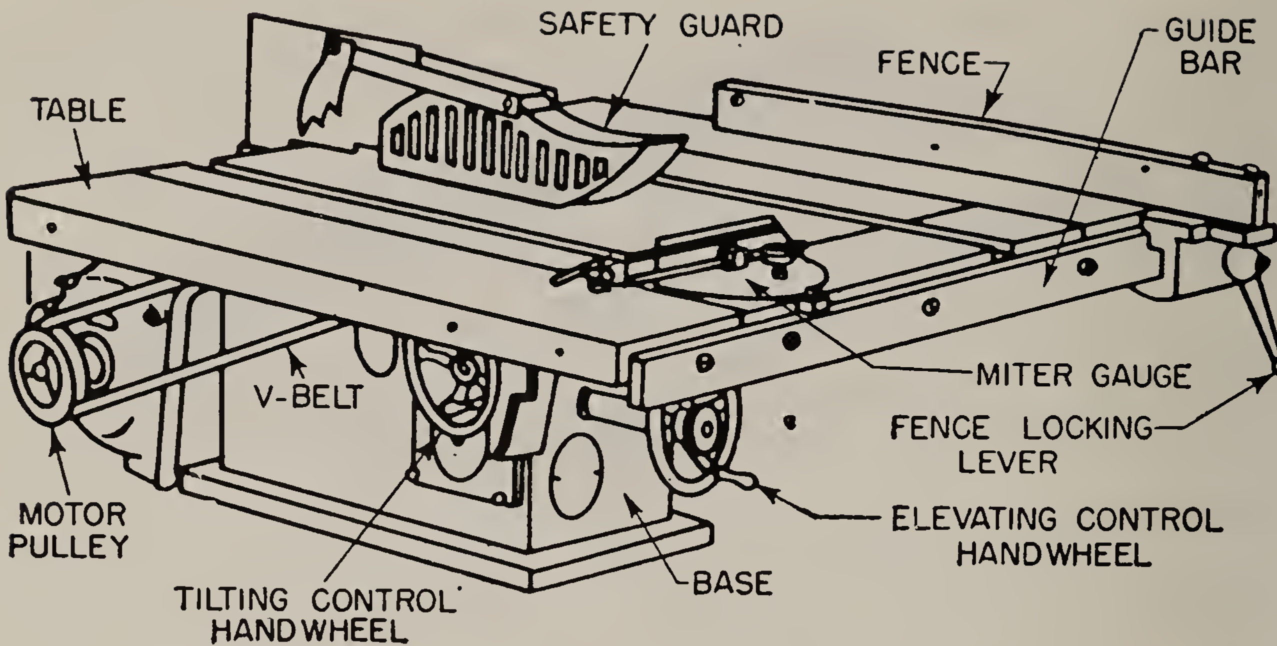


Fig. 11. Typical eight-inch, tilting-table saw. It has a speed of 3,450 rpm and is equipped with a cast-iron table, fence, miter gauge, and a safety guard which includes two antikickback pawls and splitter. Elevating mechanism consists of a handwheel which tilts the table by screw and nut action.

blade. The gauge may be used in either table groove, although most operators prefer the left-hand groove for average work. It is highly essential that the miter gauge is set correctly in order to obtain a square cut; therefore, it is customary to test the work by means of a try square before proceeding.

Mitering Operations—Most miters are cut to an angle of 45 degrees because four pieces cut at this angle will make a square or a rectangle when assembled. Miters are cut by setting the miter gauge at the required number of degrees. The angle of the miter for any regular polygon is obtained by dividing 180 degrees by the number of sides and subtracting the quotient from 90 degrees. Thus, for example, to find the angle of a pentagon (5 sides) we have $90 - 180/5 = 54$ degrees. Similarly, the angle for the miter of an octagon (8 sides) will be $90 - 180/8 = 67.5$ degrees, etc. The gauge may be used in either of the table grooves and also may be set on either side of the center position. When great accuracy is required on miter cuts, special miter-clamp attachments are used.

Grooving Operations—These operations consist of making grooves that are wider than those cut by ordinary saw blades. Grooves of varying width are commonly cut on a circular saw by employing a special attachment known as a *dado head*. This is

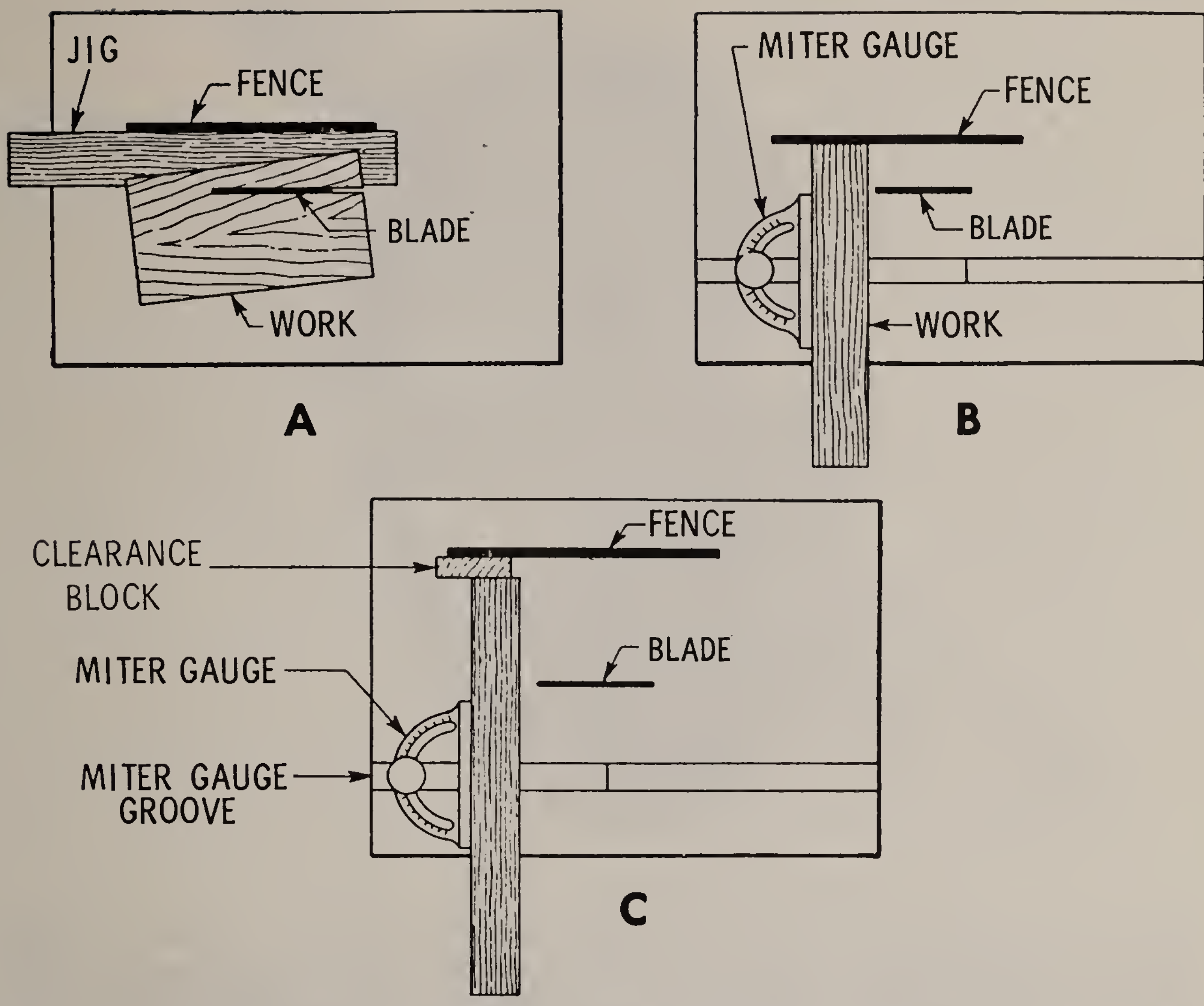


***Fig. 12.** Typical sawing operations on circular saw. In taper ripping such as shown in (A), work which is to be ripped on a taper cannot be guided against the fence but must be held in a tapering jig. The same idea can be applied to a number of other forms. In cutting shoulders, the stock should first be squared on one end and cut to the length. The miter gauge is used in connection with the fence to bring the shoulder cut the correct distance from the end as shown in (B). In crosscutting wide pieces to length, one end should first be squared and the gauge adjusted to the required length. Narrow pieces may be sawed to length by placing a block against the fence as shown in (C), the distance from the saw blade to the block being the required length.*

made up of two outside cutters and three or four inside cutters (as shown in Fig. 13) by means of which grooves varying in width of from ⅛ to 13/16 in. or larger can be made by using different combinations of cutters.

Grooves cut across the grain are termed *dadoes*. They are usually cut at right angles, but also may be cut at other angles. Dadoes which do not extend entirely from side to side of a board are termed *stopped dadoes*, *blind dadoes* or *gains*. A gain may have one open end, or both ends may be closed.

Power and Speed—The required power for circular saws may vary widely depending upon the use. The actual power required

Fig. 13. Typical dado-head assembly. A dado head such as shown is made up of two outside blades ⅛ inch thick together with one or more cutting fillers 1/16 inch and ⅛ inch thick depending on the width of the groove desired. Grooves varying in widths up to one inch can be cut.

will depend upon: thickness of cut, rate of feed, kind of wood, and condition of saw blade. Thus, for example, a heavy duty ripsaw blade of the sawmill type will require from 50 to 100 horsepower, whereas a typical 8-inch circular saw blade used in the average home workshop will require a motor of from ⅓ to ½ horsepower. A typical spur-feed ripsaw used in a woodworking plant requires a motor of from 5 to 10 horsepower.

Speed is indicated by the number of revolutions per minute made by the saw and also by the number of feet traveled by the rim per minute. Motor-driven circular saws with motor directly connected to the spindle usually run at 3,600 revolutions per minute (rpm) on 60-cycle current. The speed can be adjusted to a suitable value by means of two pulleys of unequal diameter, one on the motor shaft and the other on the saw arbor. It is a mistake to run any saw faster or slower than the manufacturer recommends, because saw blades are tensioned to run at a certain speed and give best results at that speed.

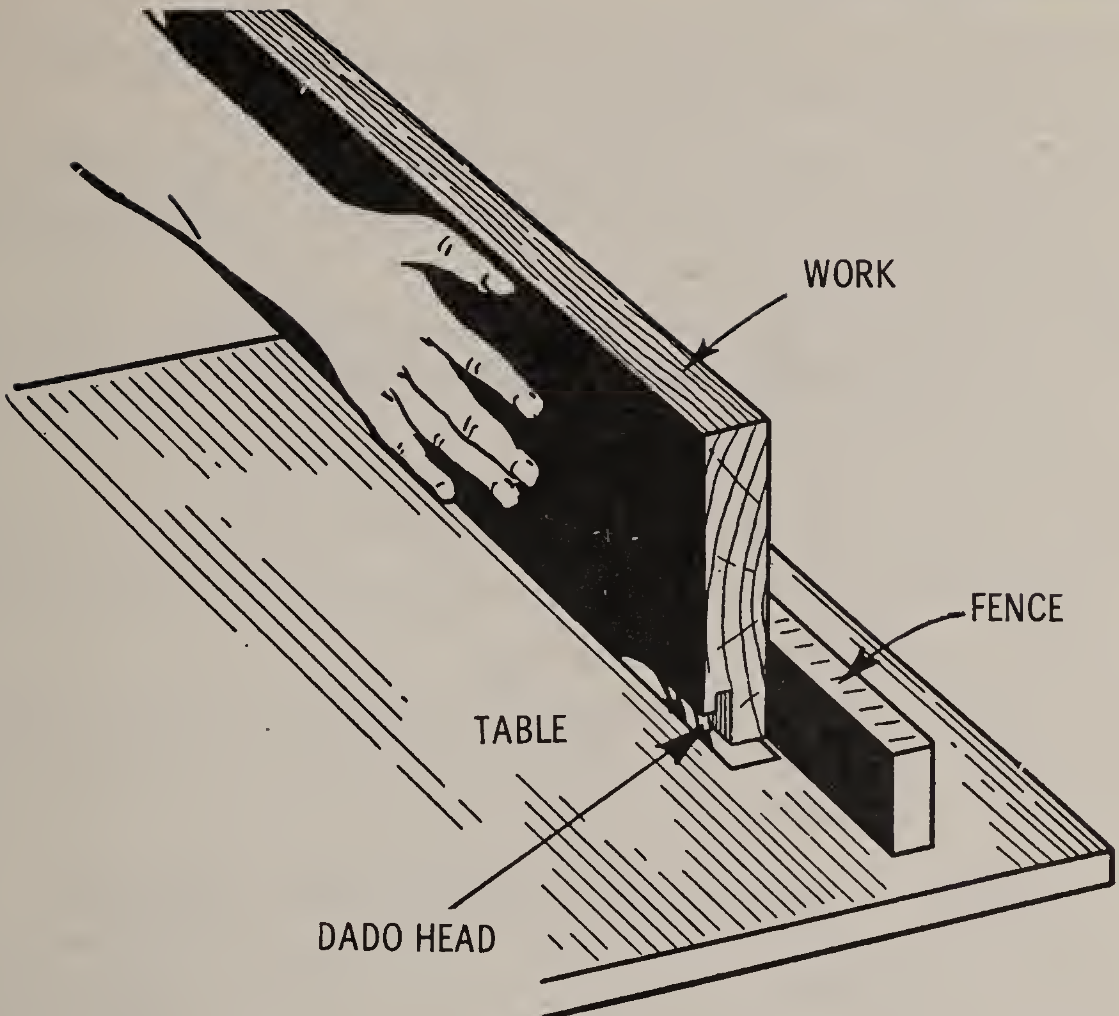


Fig. 14. Method of cutting a rabbeted joint with a dado head. Joints of this type are used extensively in drawer construction.

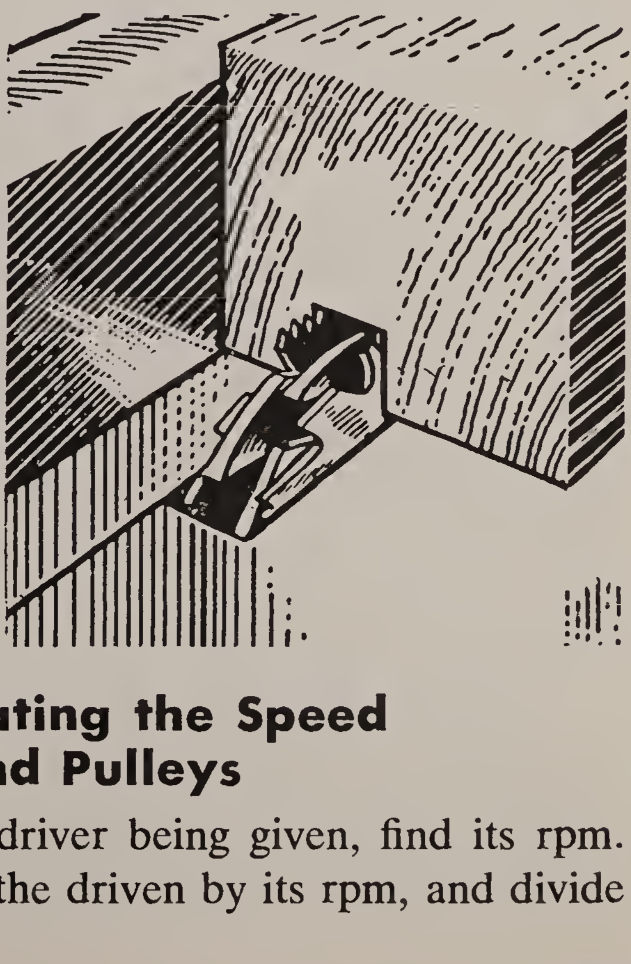


Fig. 15. Method of cutting wide grooves with dado head.

Rules for Calculating the Speed of Saws and Pulleys

Problem: The diameter of the driver being given, find its rpm.
Rule: Multiply the diameter of the driven by its rpm, and divide

the product by the diameter of the driver; the quotient will be the rpm of the driver.

Problem: The diameter and rpm of the driver being given, find the diameter of the driven, that will make a required number of rpm in the same time.

Rule: Multiply the diameter of the driver by its rpm, and divide the product by the required rpm of the driven; the quotient will be the diameter.

Problem: To ascertain the diameter of the driver.

Rule: Multiply the diameter of the driven by the rpm desired and divide the product by the rpm of the driver; the quotient will be the diameter of the driver.

Table 1. Speed of Circular-Saw Blades

Size of Saw Blade	*Rev. per Min.*
8 in.	4,500
10 in.	3,600
12 in.	3,000
14 in.	2,585

The values in the foregoing table apply to solid-tooth saw blades.

Rim Speed—A speed of 9,000 feet per minute for the rim of a circular-saw blade may be laid down as a rule. For example, a blade 12 inches in diameter is three feet around the rim and should rotate at 3,000 rpm. Of course it is understood that the rim of the saw blade will run a little faster than this calculation, because the circumference is slightly more than three times as large as the diameter.

CHAPTER 10

The Circular Saw

Types of Saw Blades—The efficiency of a circular saw depends mainly on the type of blade used and the condition of its blade. There are three general types of circular-saw blades. They are:

1. Crosscut.
2. Ripsaw.
3. Combination.

The crosscut blade is intended for cutting across the grain and is not satisfactory for ripping. The gullets of crosscut blades are quite sharp, yet they should be slightly rounded in order to prevent cracking. For general crosscutting, an 8-inch or 10-inch blade with 100 teeth is most commonly used.

The ripsaw blade, as the name implies, is used for ripping or cutting with the grain of the wood and is not suitable for crosscutting. Ripsaw teeth are filed to several different patterns. The shape of the tooth, the gullet space, and the clearance at the back of the tooth are important factors. The standard ripsaw blade has a series of chisel teeth with a sufficient amount of back clearance to prevent drag. Authoritative tests have shown that a tooth space of 1¼ inches from point to point is ideal for lumber up to 2 inches in thickness. For coarse ripping on heavy work, wider spacing is desirable. For fine ripping, closer spacing gives better results.

The combination saw blade has two types of teeth: cutting teeth shaped like those in a crosscut blade which do the rough cutting, and chisel-shaped *raker* or cleaner teeth which give the kerf a

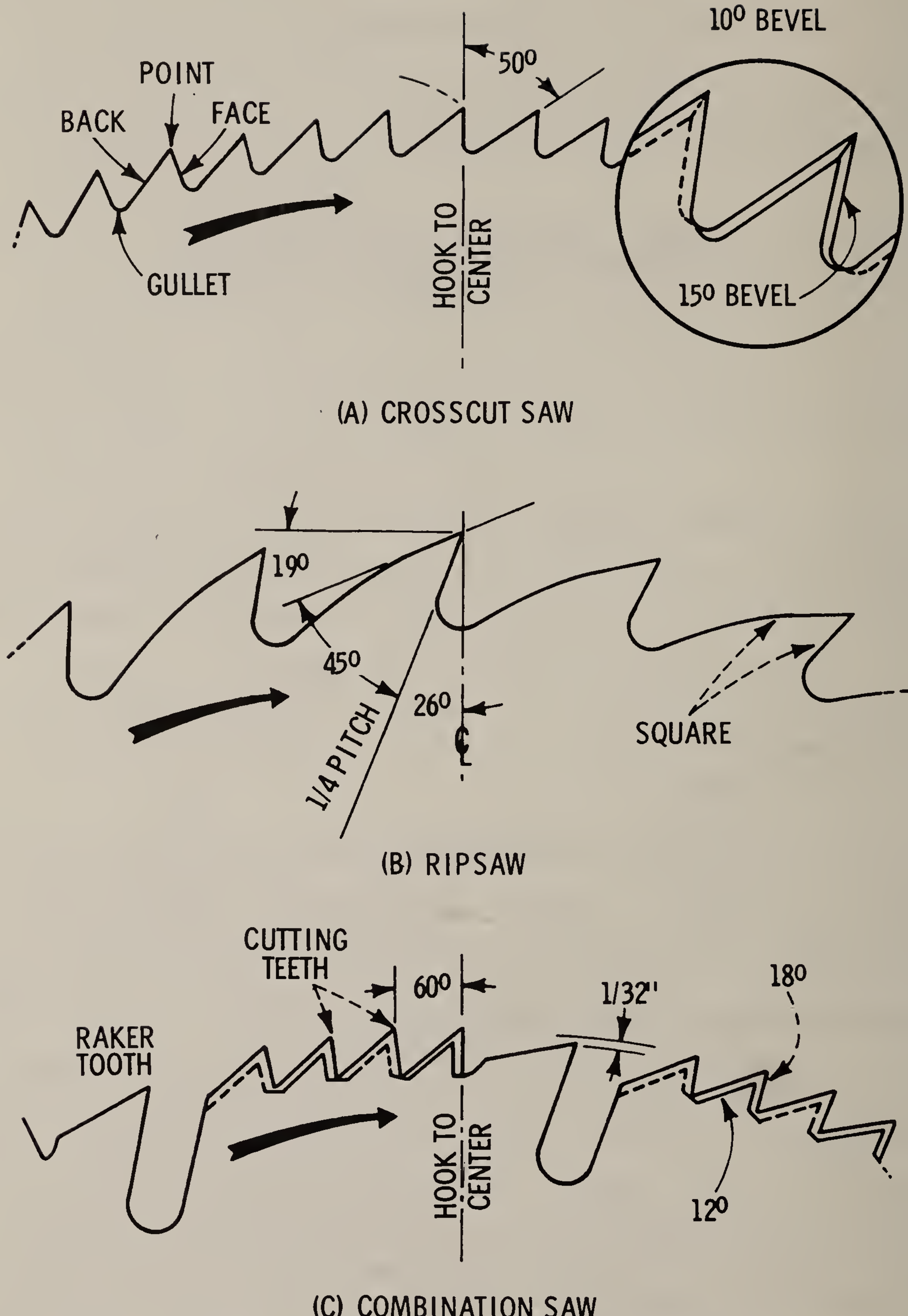


Fig. 1. The three principal types of circular-saw blades.

smooth finish. Raker teeth are slightly shorter than cutting teeth and have a wider throat for cleaning out chips. Usually, every fifth to eighth tooth is a raker tooth. Combination blades usually are employed on single-arbor table saws for both ripping and cross-cutting. Since the blade is hollow-ground, the teeth require no set;

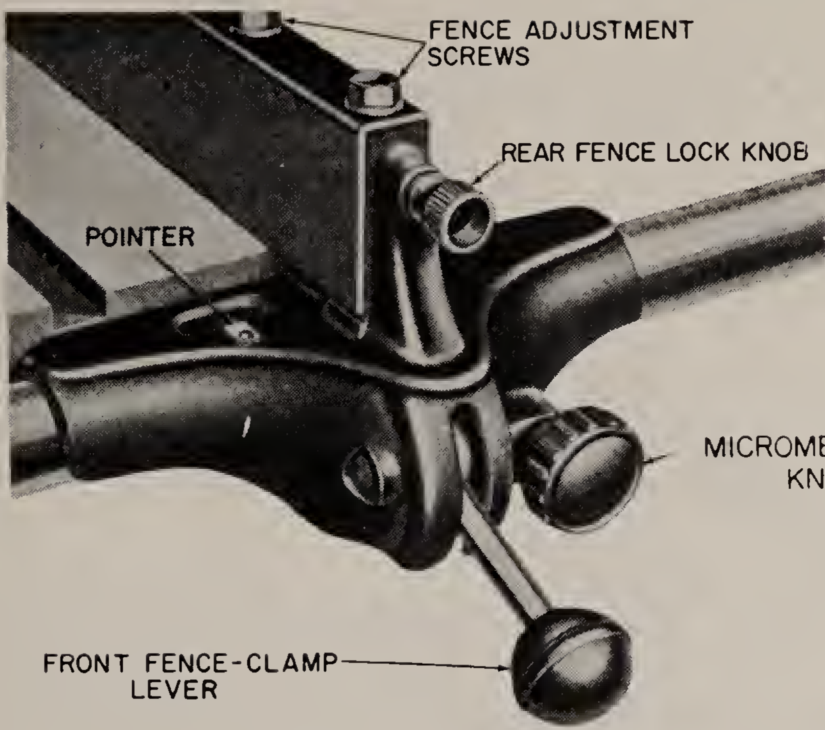
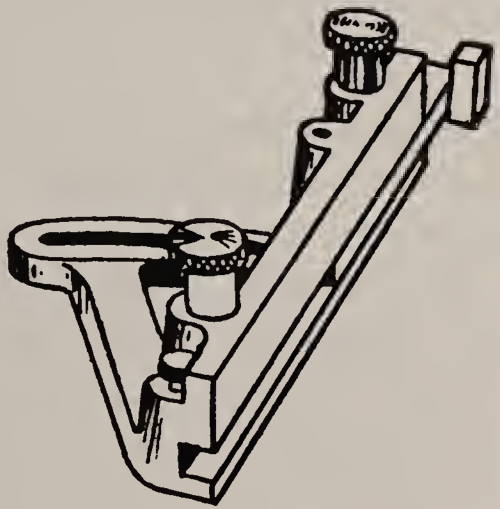


Fig. 2. Typical rip fence. Clamps are provided at both front and rear. Micrometer knob provides close adjustment.

the slight tapering from the edge to the center provides the necessary clearance.

Fig. 3. Typical cutoff gauge.



The Ripping Fence—The ripping fence (Fig. 2) is a most useful and necessary accessory. It consists essentially of a rectangular piece of steel which, because of its adjustable features, can be used as a guide when ripping stock.

Gauges—The cutoff gauge (Fig. 3) is used for crosscutting and is mounted at right angles to the saw blade, but may also be set at any desired angle. The miter gauge (Fig. 4) is also used for crosscutting, but differs from the cutoff gauge in that it is provided with

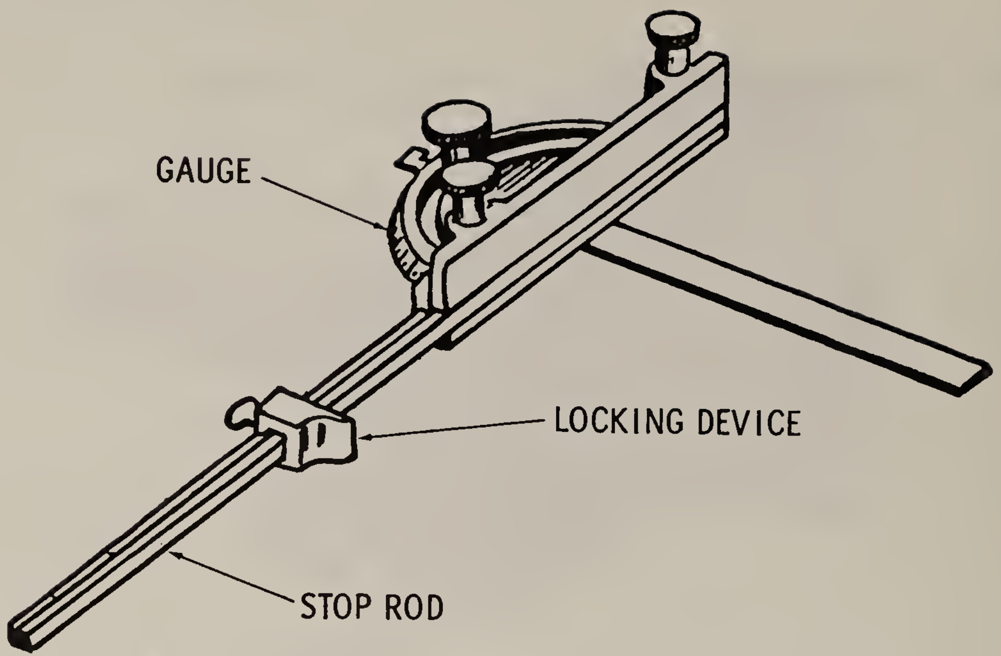


Fig. 4. Miter gauge with stop rod and stop block.

a micrometer scale and adjustment for exact angle determination. Since the saw table is usually equipped with two parallel grooves for gauge operation, the miter gauge may be used in either table groove and thus on either side of the saw blade for miter cutting. Never use the miter gauge for ripping stock.

How to Use the Ripsaw—One of the less difficult saw operations is that of making lengthwise or ripping cuts in wood. The procedure is generally as follows:

1. Attach the ripsaw blade to the arbor.
2. Raise or lower the table or blade as necessary, and set the clamp so that the table or arbor cannot move.
3. Using the scale on the table, set the ripping fence and lock it. The width of this setting should be from 1/16 to 1/8 inch greater than the desired width of the finish stock. For accurate settings, use the micrometer adjustment on the fence. Make certain that the fence carriage is resting in the locating holes and is securely fastened to the table. See that the thumbscrews which hold the fence in position are set and that the face of the fence is at right angles to the table surface. Lock the fence in position. To accommodate wide stock, move the fence carriage away from the saw to a second or third set of locating holes.
4. See that table is level and at right angles to the saw blade and that the guard is in position over the saw blade.

5. Standing at left of the work, place the straight or jointed edge of the stock against the fence and feed the stock against the saw blade.
6. When ripping stock into narrow strips, use a push stick such as is shown in Fig. 5. The guiding properties of the push stick will be considerably improved by the cutting of a notch in its base as illustrated.

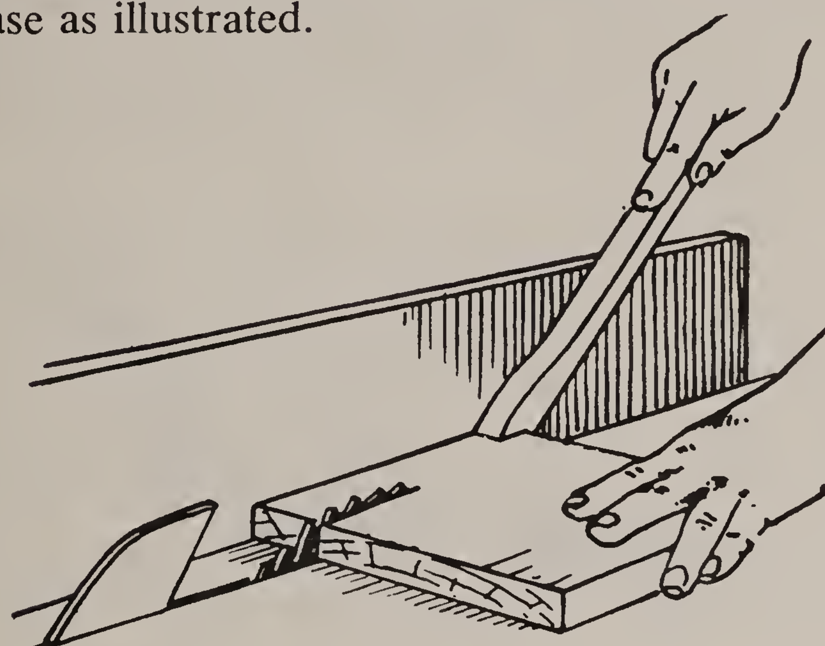


Fig. 5. Method of ripping stock to suitable width by employing a push stick as a safety device. Guard is removed for purposes of illustration.

7. When ripping wide stock, support the stock with the hands and hold it against the ripping fence. Keep to the side of the machine and force the stock steadily ahead while holding it firmly against the ripping fence.

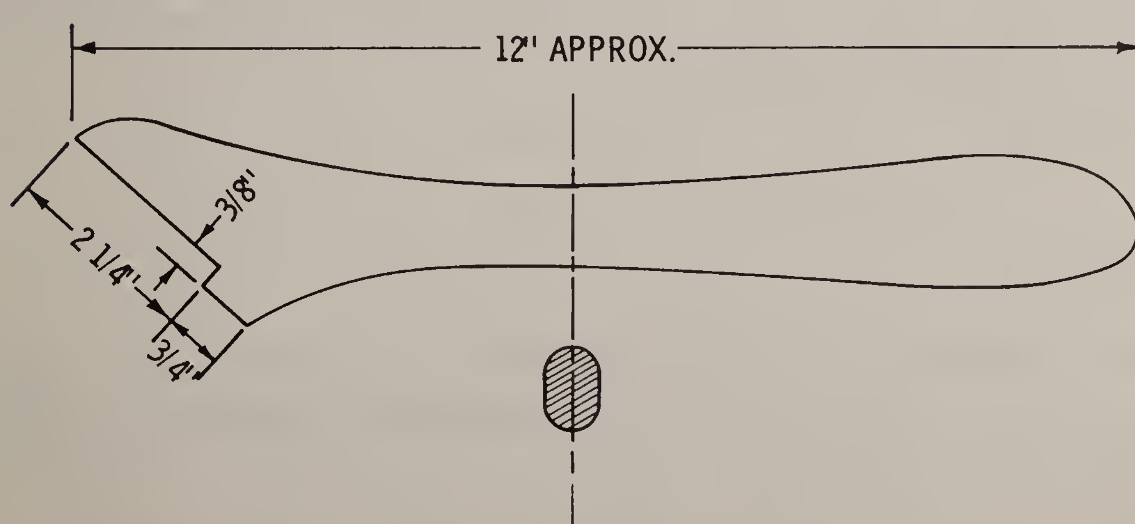


Fig. 6. Push stick used to protect hand of operator when working in close proximity to saw blade. Push sticks are usually made from a suitable piece of hardwood cut to the appropriate dimensions shown.

Rabbeting—A rabbet is a rectangular groove cut on an adjoining edge and face of a board. It is commonly used on mirrors, pictures, and window and door frames and is formed by making two saw cuts at right angles to each other. To make rabbet cuts, proceed as follows:

1. Set ripping fence for desired width of face kerf and adjust the saw vertically for depth of cut.
2. Remove both the splitter and the saw guard because they cannot be used.
3. With the edge of the stock against the fence, make the first cut. Hold the piece against the fence with the left hand, but use a push stick in the right hand next to the fence.
4. Reset saw and rip fence if necessary.
5. With the stock resting on edge and with the face against the fence, make a second cut to remove the waste strip and form the rabbeted edge.
6. To form a tongue, rabbet the same edge on both sides of the board.

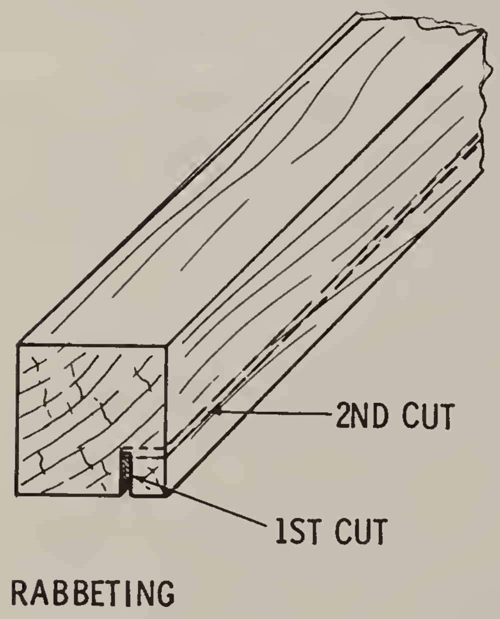


Fig. 7. Cutting rabbets on circular saw. As noted in the illustration, the first cut is made to completely clean out the corner and finish the rabbet.

Angle Ripping—Stock can be chamfered, beveled or ripped at an angle by tilting either the blade, table or fence, depending on the type of saw.

1. To rip stock at an angle by tilting the fence, adjust table and saw blade for simple ripping and tilt fence at the desired

angle of cut. Narrow stock lies against the fence easily and can be handled in the same manner as for simple ripping. With wide stock, however, the overhanging weight may pull the stock away from the fence, changing the angle and the cut. Cut wide stock at the correct angle by one of the following methods:

(a) Hold wood against the fence with left hand and keep stock from tilting with right hand.

Fig. 8. Method of bevel ripping, using push stick with stock against rip fence.

(b) Use a feather board as illustrated in Fig. 9. The feather board holds the stock against the fence and acts as a guard, protecting the operator from the saw blade; the latter is important because the saw guard cannot be in place for this operation. Raise or lower the feather board as required, by clamping different thicknesses of stock under it. A feather board can be made easily and quickly from a scrap board. The additional safety afforded the operator is well worth the small amount of time required to make a feather board.

2. To rip stock at an angle by tilting the table, adjust table at desired angle and lock the fence in position at left side of table. The slope of the table holds the stock against the fence and keeps it from crowding the saw blade. Stand at

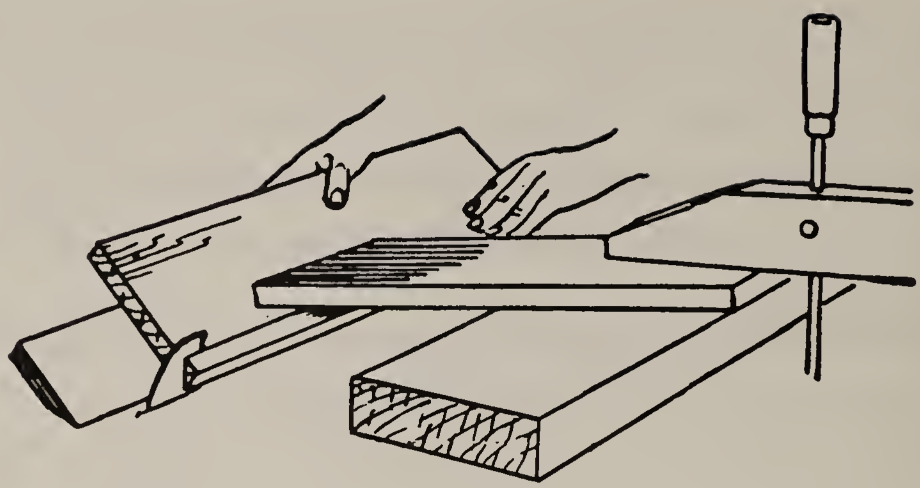


Fig. 9. Use of feather board when ripping stock at an angle.

left of table because waste stock, on right, drops against saw blade and may be thrown to front of machine.

How to Use the Crosscut Blade—Cutting with a crosscut or combination blade is accomplished by placing the work against the miter gauge and then advancing both the miter gauge and the work toward the saw blade. It is essential that the edge of the work which goes against the miter gauge be straight, otherwise the work may twist and kick back as it is advanced against the saw blade.

Squaring Stock—To square ends of stock, proceed as follows:

1. Move the ripping fence to the right or remove it entirely.
2. Check the miter gauge for squareness by placing the miter

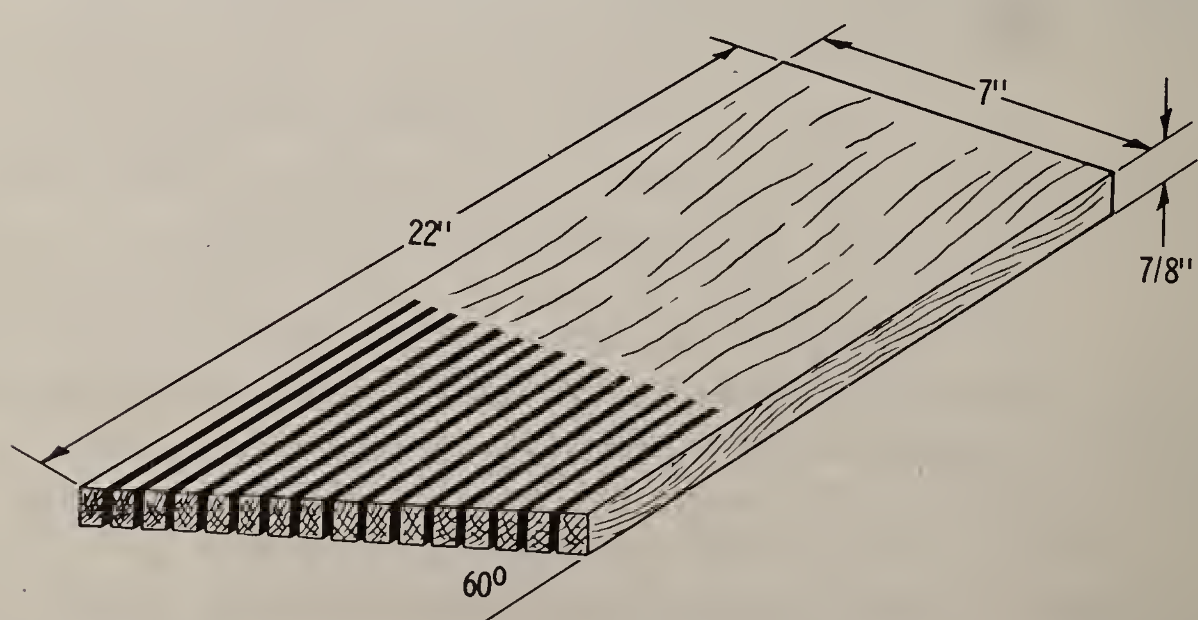


Fig. 10. Approximate dimensions and construction of typical feather board.

gauge upside down against the front edge of the table while the slide is loose in the miter gauge slot or groove of the saw table. When the gauge is squared, clamp parts securely together, turn the gauge over, and replace it in the groove on the left side of the table. Usually an engraved line on the table shows the exact location of the saw blade with respect to width of the stock to be cut.

3. Prior to starting the motor, see that all movable parts are securely clamped and that the table surface is at right angles to the saw blade. For all simple cutoff sawing, have the guard in place over the blade.
4. Place stock on table with jointed surface down and jointed edge against the miter gauge. Hold stock securely so that it will not move lengthwise along the miter gauge. A stop is not used when squaring the first end, but may be used for cutting to length.

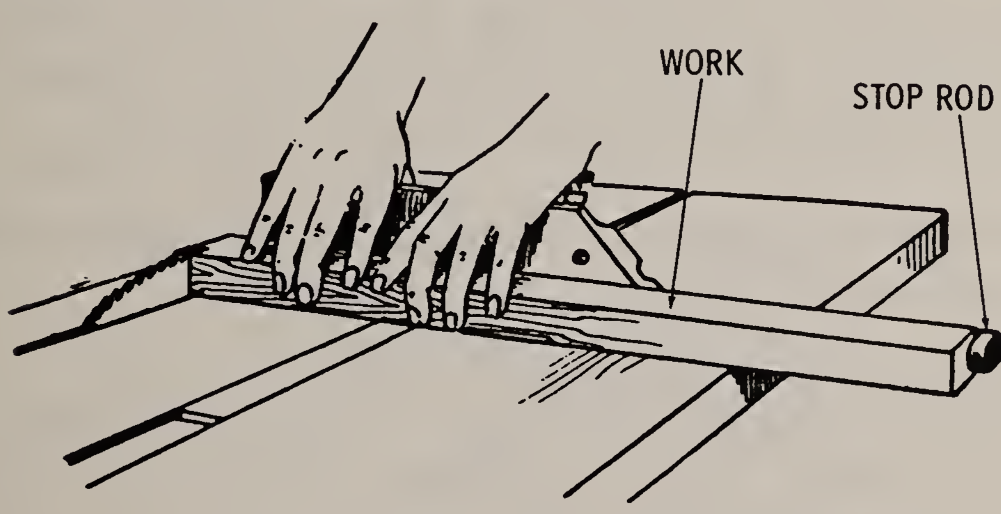


Fig. 11. Method of squaring stock on circular saw. Guard is removed for purpose of illustration.

5. Push stock against the blade, permitting enough stock to project beyond the line of the blade to square the entire end. Several pieces may be cut at one time.
6. Before squaring the second end, lay off desired finished length of stock along table, measuring from left edge of saw kerf, and clamp a stop rod in the slot of the miter gauge at that point. If stop rod supplied with the gauge is too short, use strips of wood clamped to miter gauge. When handling long stock, remove ripping fence from table top.
7. Push stock against blade and cut to finished length. When

duplicate short-length stock is required and a short rod with pin stop is used, make sure that the stop rod does not extend

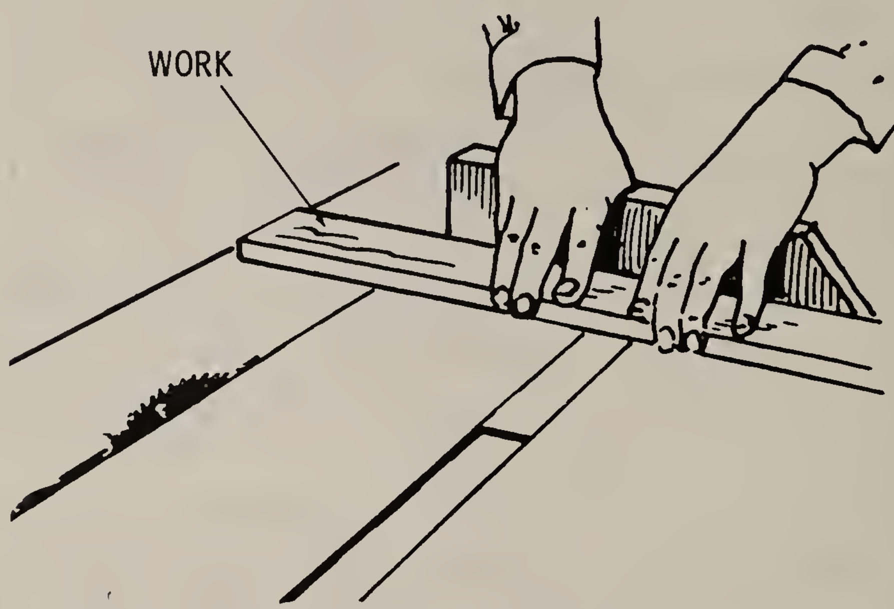


***Fig. 12.** Method of cutting longer pieces of stock to length on circular saw. Guard is removed for purpose of illustration.*

into the path of the saw blade. Reverse the rod, end for end if necessary, or use a wooden stop block clamped to the miter gauge with a C-clamp or small hand screw.

Cutting Long Stock—To cut long stock into duplicate shorter pieces, proceed as follows:

1. Square first end of stock as previously described.
2. Attach wooden clearance block to ripping fence with hand screw. Adjust fence on right side of table so that distance from clearance block to right edge of saw blade equals the desired length of stock.
3. Butt the squared end of stock against clearance block and cut to desired length, feeding stock with miter gauge.

Cutting Dadoes and Gains—Grooves cut across grain are termed dadoes. Although usually cut at right angles, they may be cut at other angles as well. Dadoes which do not extend from side to side of the stock are commonly termed *stopped dadoes, blind dadoes* or *gains*. To cut dadoes or gains with a crosscut blade proceed as follows:

1. Adjust table and fence as for simple crosscutting. Set saw

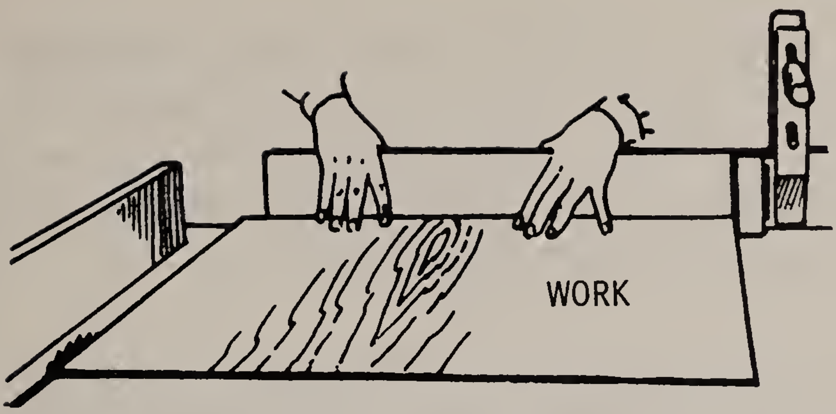


Fig. 13. Squaring end of wide board held against stop block to prevent sliding. Guard is removed for purpose of illustration.

blade so that amount of saw blade above table equals depth of the dado or gain.

2. Butt the stock against fence or against a stop adjusted for each cut. Number of cuts determine width of dado or gain. Move the stock one blade thickness for each cut.

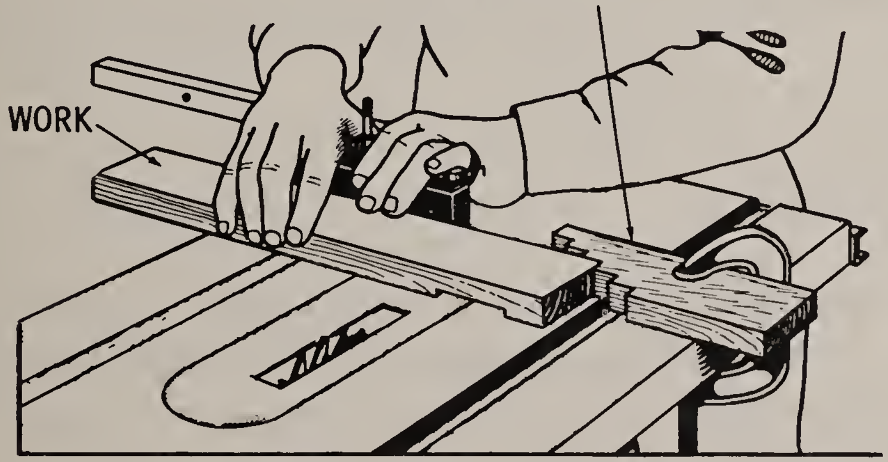


Fig. 14. Method of using gauge block when cutting several wide grooves or tenons to size.

3. If limits of the dado or gain are laid out with a knife, make one cut just inside each knife line. Remove remaining stock by a series of cuts.
4. When corresponding dadoes are to be made, as on opposite ends or sides of a cabinet, cut both dadoes with the same setup.
5. Cut gains or stop dadoes only part way across the stock. Square the ends of the cuts with a sharp chisel.

Miter Cutting—Most miters are cut at an angle of 45 degrees, because four pieces cut at that angle form a square or rectangle

when joined together. The 45-degree angle accordingly is used in the fabrication of picture frames, door and window framing, and numerous other articles. Miters are easy to cut on the circular saw. To cut a simple miter from edge to edge of a piece of stock, as for picture frames, proceed as follows:

1. Adjust table and blade in the same manner as for cross-cutting. Set the miter gauge at the desired cutoff angle.
2. Attach stop to gauge, to keep stock from slipping. Work being mitered, unless held very tightly, has a tendency to creep ever so slightly while the cut is being made. This creep is toward the blade, not away from it, and is equal to the set

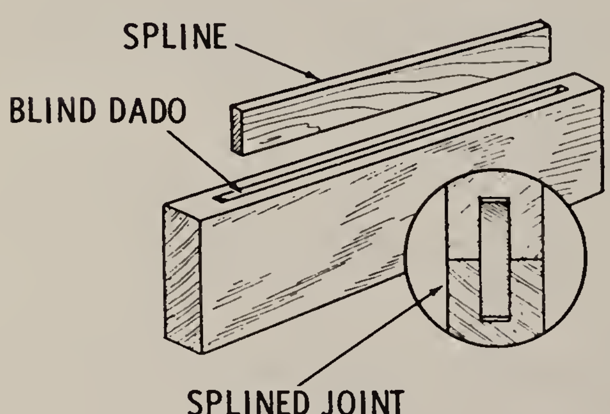


Fig. 15. Blind dadoing using a spline in joining two or more pieces of stock.

of the blade or the amount of taper on hollow-ground blades. Stock can be clamped to the miter head to prevent creeping.
3. Cut all miters from the same working face or edge to insure an accurate fit of the joint.

Compound Miters—A compound miter cut is one in which the cut slants from face to face and from edge to edge as on a box with slanting sides. To make such a box, both the table (or blade) and the miter gauge must be set at an angle. The proper angle settings for table (or blade) and miter gauge, for a square, hexagonal, or octagonal box, at any angle up to 45 degrees, may be obtained from the compound-miter diagram shown in Fig. 17. To cut a compound miter, therefore, proceed as follows:

1. Determine angle of taper needed for sides.
2. Locate desired angle of taper for box or article desired. Read angles of table (or blade) setting on horizontal scale and

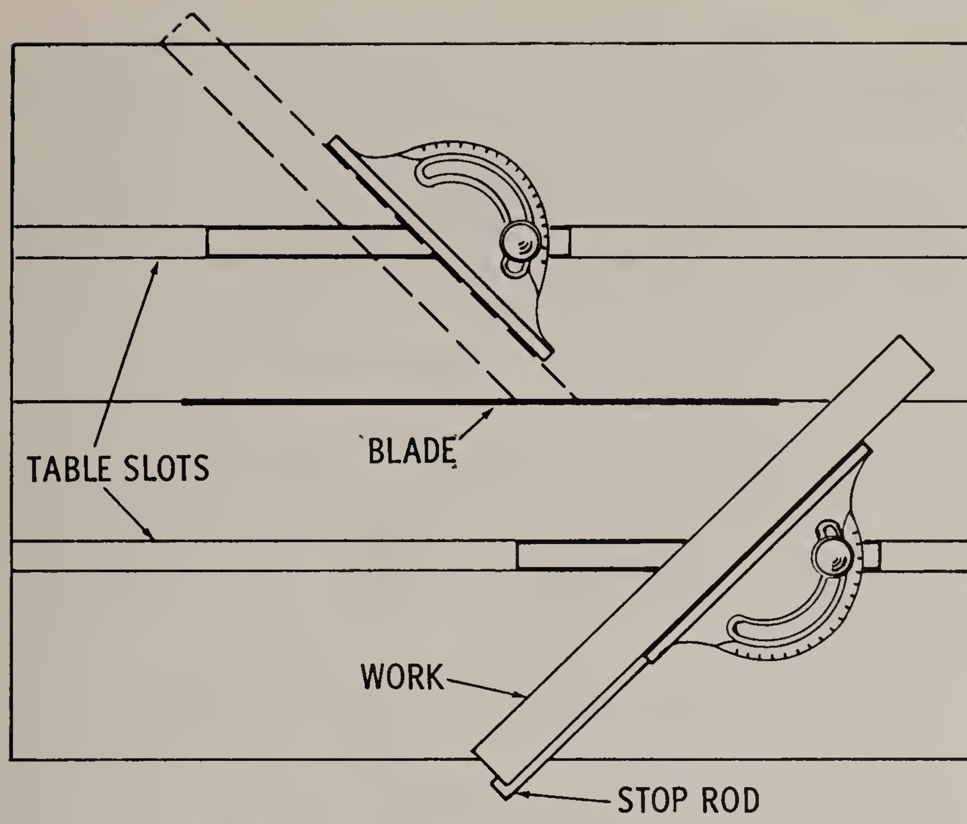


Fig. 16. Cutting miters by use of two miter gauges. When using a setup of this sort, the first cut is made to right of saw blade. The end is butted against stop rod on miter gauge to left of saw blade and a second miter cut is made.

miter gauge setting on vertical scale. Thus, for example, for a square box having sides tapered at an angle of 25 degrees, the table (or blade) setting (in degrees off vertical) should be 39° 50′. The gauge setting (in degrees off line of saw blade), read from the vertical of the diagram, is 23° 5′. Similarly, if the square box were to have its sides tapered at 20 degrees, the table (or blade) and gauge settings would be 41° 45′ and 18° 45′ respectively.

3. After a careful setting of the respective angles, the cuts are made in the conventional manner.

Splined Miter Joints—Miter joints do not make strong connections unless they are reinforced. Splines are often inserted to increase the strength. Splined joints can be made with either the table or the fence tilted, as follows:

1. Tilt the ripping fence so the beveled edge of the stock rests on the saw table. Move the fence close to the blade so that the cut will be close to the inside edge of the bevel, where

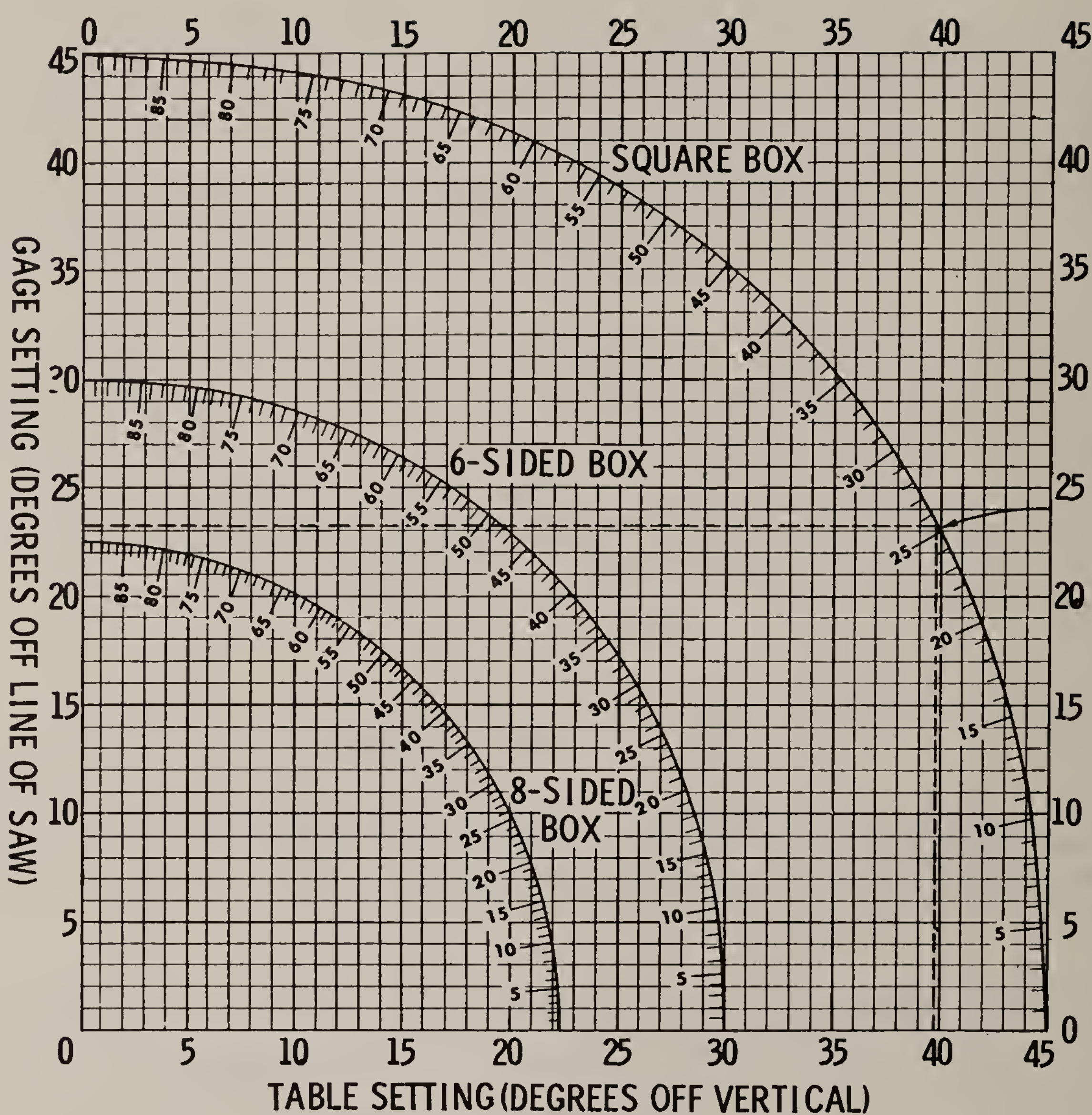


Fig. 17. Chart for determination of correct angles when cutting compound miters.

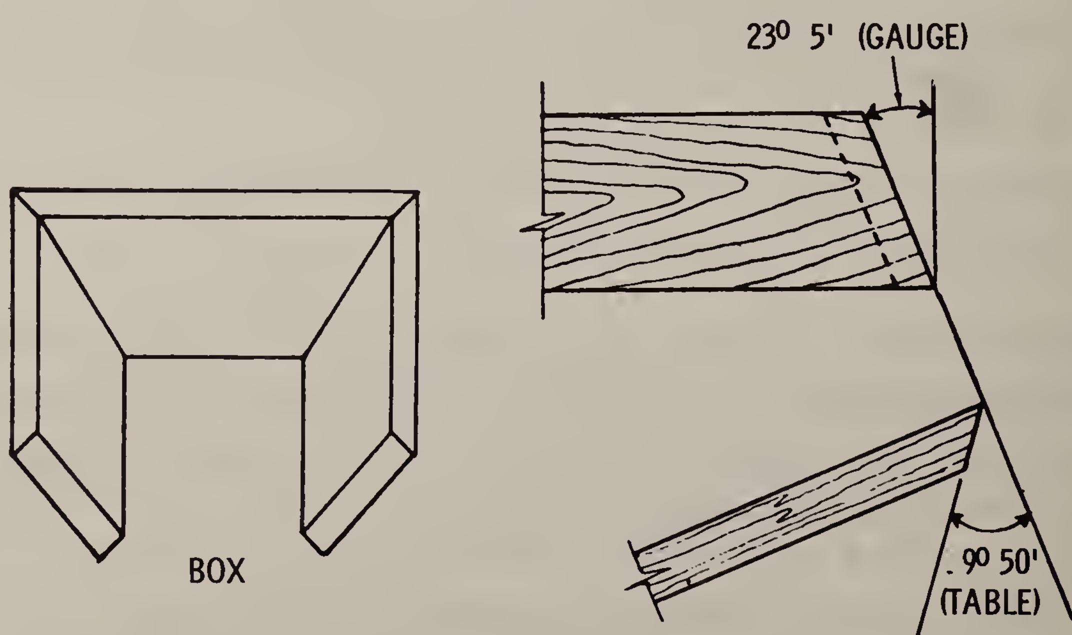


Fig. 18. Square box with sides tapered 25 degrees. See chart (Fig. 17) for method of finding correct gauge and table setting.

stock is thicker and the cut can be deeper. Use the micrometer knob for fine adjustment of fence.
2. Set the blade for desired depth of cut.
3. Use a push stick cut square on the end, or at the proper angle for a compound miter, to keep the stock from tilting and to hold bevel on the table. A feather board helps keep the work at the desired angle against the fence.
4. Using same settings for the fence and saw blade, cut a groove in both bevels of the miter joint.
5. Insert spline, making sure its grain runs across the joint at approximately right angles to the bevel.

Using the Dado Head—Grooves, rabbets and dadoes are preferably cut by means of the dado head. A dado head consists essentially of two outside cutters similar to combination blades which cut along the outside limits of the work, and several chisel-like inside cutters of various widths which remove the stock left between the outside kerfs. Thus, the dado head functions in the manner of a thick saw blade, which, depending upon the number of cutters used, will cut a kerf of from ¼ to 1 inch in width. Make sure of correct dado width by trial cuts on waste stock.

The dado head cuts equally well with the grain or across the grain. Some saw tables slide sidewise to permit insertion of the wide head. On others it is necessary to use a special plate with an opening large enough to accommodate the dado head.

Assembly and Mounting of the Dado Head—The simplest type of dado head consists of two blades or outside cutters and three or four inside cutters. To set up the saw table for a dado head, proceed as follows:

1. Open table, remove the conventional blade, and screw a dado-head sleeve on the saw arbor.
2. Mount one of the blades which resemble a combination blade on the arbor, then mount one or more of the inside cutters, then mount the other blade and finally the collar and nut which locks the whole assembly. The inside cutters should be placed so that their points will be in the gullets of the blades as shown in Fig. 19. Use one outside blade for

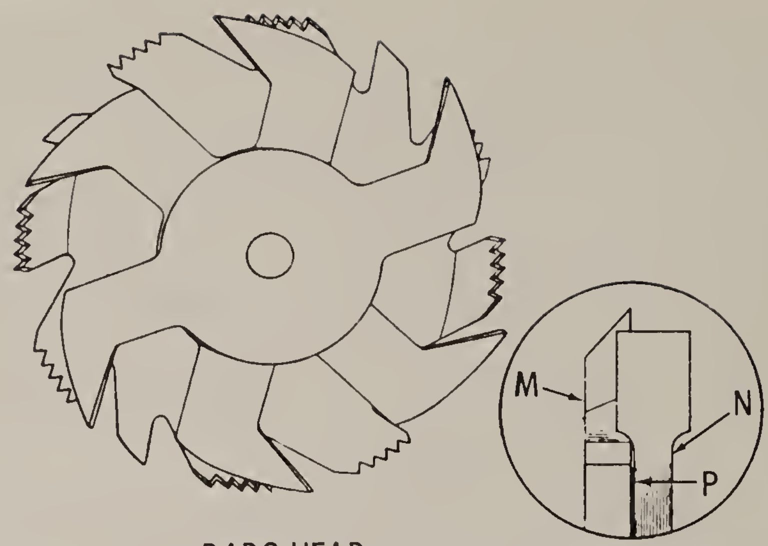


Fig. 19. Method of cutter assembly for typical dado head, with one of the outside cutters removed for the sake of clarity. In the assembly, paper washers may be added between cutters for fractional expansion as shown at P, with M and N being outside and inside cutters, respectively.

a ⅛-inch cut, both outside blades for a ¼-inch cut, and as many inside cutters as required for wider cuts.

3. Close table by sliding it laterally toward the dado head, or use dado table plate. See that the dado head revolves freely and that the holding nut is properly tightened before starting the motor.

Cutting Grooves and Rabbets with Dado Head—A groove is a furrow or channel cut with the grain on the face of a board. A rabbet, on the other hand, is a rectangular groove cut on an adjoining edge and face of a board. To cut grooves and rabbets, set the dado head for width of cut, and raise or lower the table or blade to cut desired depth. Adjust the ripping fence to locate the groove or rabbet and proceed as for simple ripping. Make certain that stock edges are parallel. If a rabbet is to be cut on a piece without parallel sides, the edge to be rabbeted is held against the fence. In this case, a wooden faceplate must be attached to the fence so that the cutter head just touches it and makes a clean cut in the work.

Dadoes and gains are cut in the same manner as grooves and rabbets, but are cut across the grain of the wood. For right-angle cuts, use a miter gauge tested for squareness. To cut dadoes or gains at an angle, adjust gauge to the desired angle. For woodwork of this sort, special *grooving* and *molding heads* can be used.

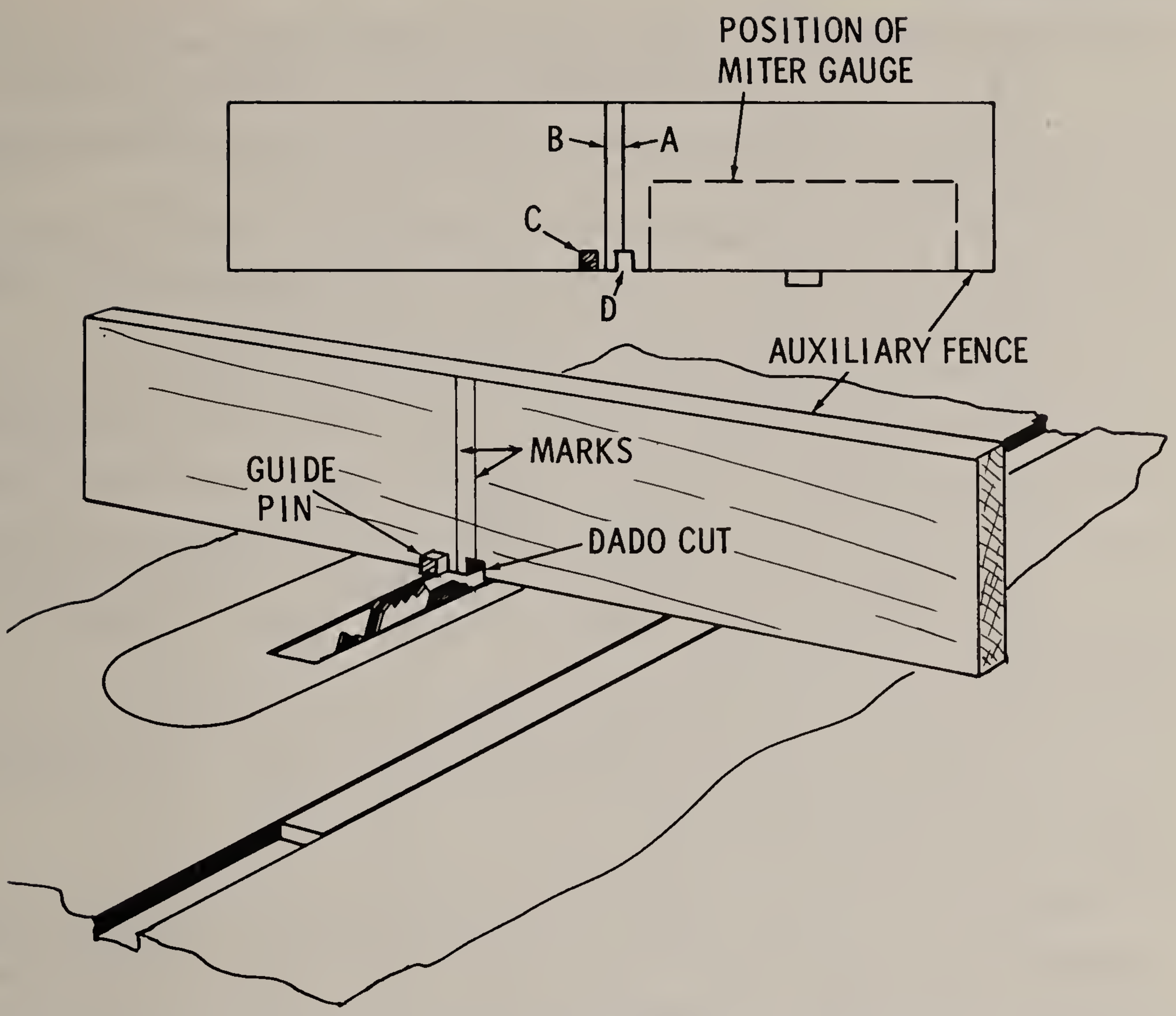


Fig. 20. Jig for cutting evenly spaced dadoes and method of placement on saw table.

These consist essentially of round or square metal heads with specially shaped cutters and spurs attached. The spurs slit the wood ahead of the cutters so that sides of the cuts are smooth.

Cutting Evenly Spaced Dadoes—Evenly spaced dadoes are used in box joints and, when cut at an angle as for louvers or slots in doors and windows, may be cut on the circular saw by employing the following procedure:

1. Mark out two of the dado cuts to be made in the stock.
2. Set up the dado head to the thickness and depth of the cuts and remove the ripping fence.
3. To set up the work, it is necessary to have an auxiliary wood fence which can be screwed to the standard miter gauge.
4. Hold the auxiliary fence firmly against the miter gauge and run it across the dado head near its center.

5. Remove the fence, and mark the position of a second cut D, Fig. 20, spacing this from the first cut C, the same width as the dado. At the same time, mark the lines A and B, centering them as shown.
6. Now, nail a square piece of wood in the first dado cut as noted in Fig. 20, and make the second dado cut, D, with the auxiliary fence fastened to the miter gauge.
7. To make the joint, the two pieces of stock that are to be joined are set against the fence, the edge of one piece being even with line A, while the edge of the other piece is set even with line B. The work is then pushed across the blade, after which it is shifted so that the dadoes just cut in the two workpieces are placed over the square pin and the second cut is made.
8. The second groove is then placed over the locating pin and a third cut made, etc. Proceed in this manner until all the dadoes have been cut.

Contour Cutting—While the circular saw is intended for straight-line sawing only, it can, where the work demands, be made to cut curves of large radius. The saw-kerf method of

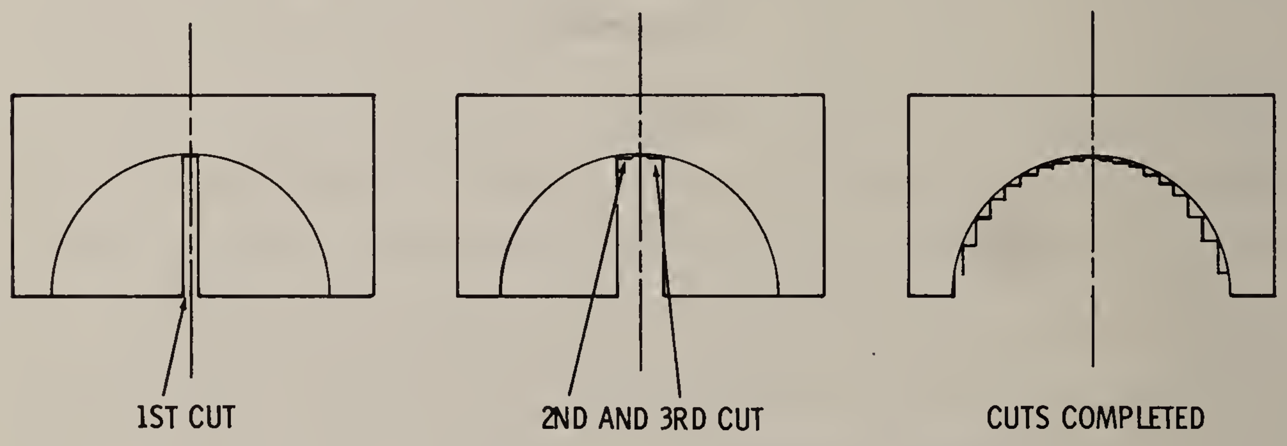


Fig. 21. Kerf method of contour cutting.

cutting concave and convex curves to an approximate shape is essentially as follows:

1. To shape a concave curve, cut stock to finished width and thickness, making opposite sides parallel. Draw a center line on the edge of the stock and lay out the contour desired.

Adjust the saw blade for the deepest kerf and cut on center line of stock as illustrated in Fig. 21.

2. Move the fence ⅛ inch away from the saw blade and decrease the depth of the kerf to follow the contour line. Cut on both sides of the first kerf, holding each edge against the ripping fence (Fig. 21).
3. Continue moving the fence and changing depth of cut until the shape is roughed out as shown in Fig. 21.
4. Finish the inside surface with a sharp gouge or a suitable core-box plane. Smooth the curved surface with molding scrapers and with sandpaper held over a four- or five-inch block of wood shaped to fit the contour of the curve.
5. When cutting a convex curve the method is the same, except that the center line indicates the most shallow cut. In shaping a semicircular piece in this fashion, the portion of the waste stock which would be removed by the last two saw cuts should be finished off by hand, to leave bearing surfaces against fence and saw table so as to prevent the stock from rolling sidewise.

Cutting Straight Moldings—In the absence of a shaper, straight moldings may be cut on the circular saw with a *molding head.* A molding head consists essentially of a steel disk one inch or more in thickness and six inches or more in diameter. It has a central hole for mounting on the saw arbor, and its circumference is fitted to receive two or three knives or cutters shaped according to the contour of the particular molding required.

1. When the saw is not equipped with a cut-out molding fence, it will be necessary to clamp or screw a board to the ripping fence as shown in Fig. 22. This is done to prevent injury to the knives and the fence and because the molding to be cut is seldom the full width of the knives.
2. In mounting knives on the molding head, a great deal of care is required to see that the knife projection is exactly equal and that the holding screws are tightened properly.
3. After mounting the molding head on the arbor, set the ripping fence to the proper width, start the motor, and

gradually raise the molding head so it cuts into the wood fence. After the necessary adjustments, a test cut on waste stock should be made to make certain that the molding is of the proper shape.

Cutting Tapers and Wedges—A board or other piece of work is said to be tapered if it is sawed or planed so that one end

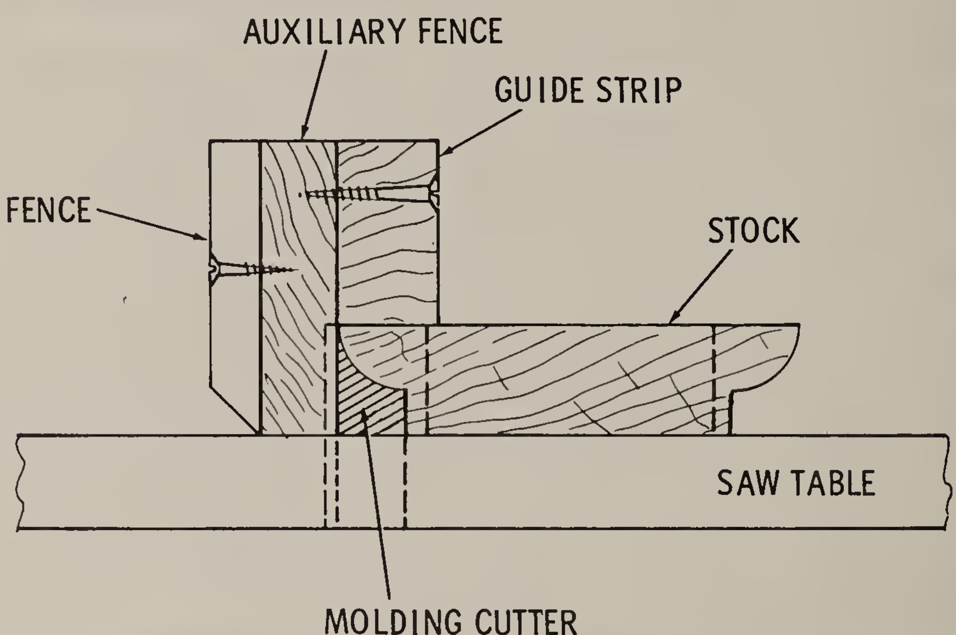


Fig. 22. Method of cutting moldings on circular saw. Moldings are ripped to size along dotted line.

is narrower than the other. Depending upon its particular use, it may be tapered on one or both sides, or on all four sides. It may also be tapered throughout only part of its length. Stock which is to be ripped to a taper cannot be guided against the fence, but must be held in some form of template or tapering jig. Any number

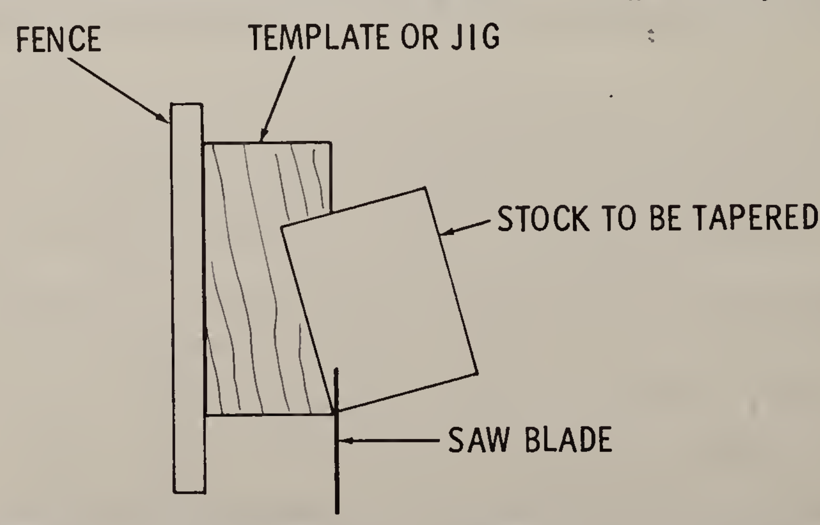


Fig. 23. Method of cutting tapers or wedges on circular saw by means of suitable template. This method of cutting is used mainly on production work where a large number of similar pieces are required.

of similarly shaped tapers can be cut by using a template, as follows:

1. Cut the shape of the taper into the edge of template stock as shown in Fig. 23.
2. Move the ripping fence so that the template just passes between the saw blade and the fence. Use a ripsaw or combination blade.
3. Fit the stock into the notch in the template and move the stock and template past the blade.
4. Switch stock end for end to taper the opposite side.

Tapering Square Legs—Square table legs can be tapered by using a template such as shown in Fig. 24 in the following manner:

1. Set the ripping fence at a distance from the blade equal to the combined width of the long template member and the leg stock, so that the blade just clears the leg when the stock is placed against the template.
2. Cut the taper on two adjacent sides with the end of the stock in the first notch as shown in Fig. 24.
3. Cut tapers on the two remaining sides with the end of the stock in the second notch.

It should, of course, be observed that the position in which the stock is placed depends upon the length of taper desired. Thus, for example, if it is required to taper a 32-inch leg for a distance of 26 inches, the stock is fastened 26 inches from the end. In sawing tapers, the saw should project about ⅛ inch above the stock as in ordinary ripping. Use the splitter guard to prevent the stock from being caught on the back of the saw.

Use of Special Tapering Jig—A special tapering jig suitable for production work is shown in Fig. 25. As noted in the illustration, the jig consists essentially of two hinged boards which may be locked into any desired position by means of a special locking device. The amount of taper per foot is equal to the distance between the boards 12 inches from the hinged ends.

Cutting Tenons—Tenons required for mortise-and-tenon joints can be made with a circular saw, using a combination blade,

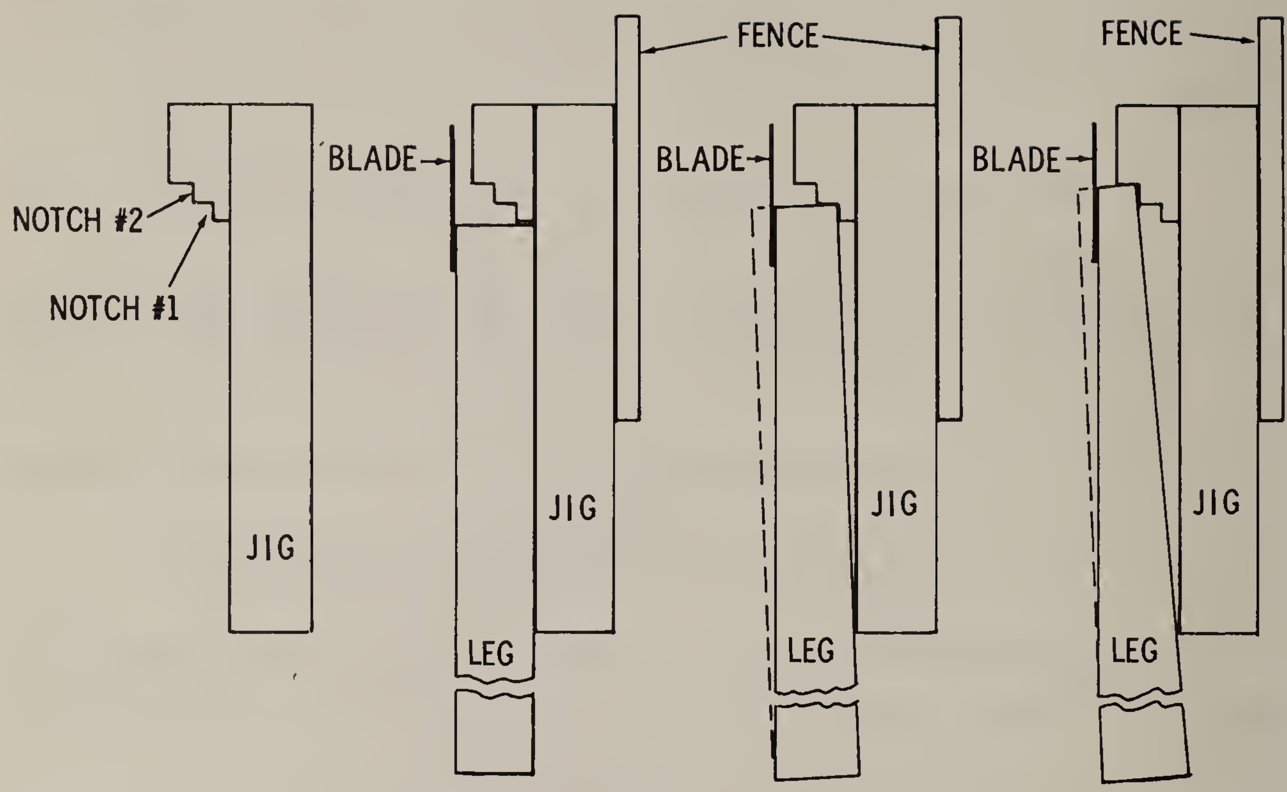


Fig. 24. Method of cutting square tapers, such as required for table legs, using equally raised notches attached to block as shown.

a dado head, or both ripsaw and crosscut blades. When cutting tenons with a circular saw, care is necessary to insure that shoulders meet at the correct angle and that tenons fit snugly into mortises. Cut tenon shoulders first, then make the cheek cuts.

Square Shoulder Cuts—To cut shoulders on square-shouldered tenons with the circular saw, proceed as follows:

1. Cut stock to finished width, thickness, and length using a crosscut or combination blade.

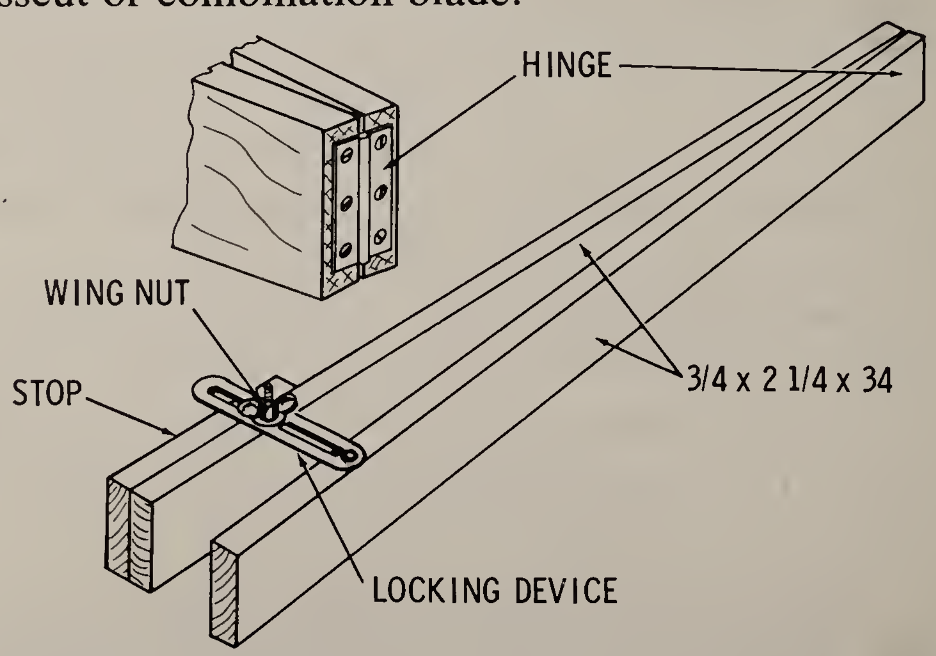


Fig. 25. Adjustable tapering jig suitable for production work.

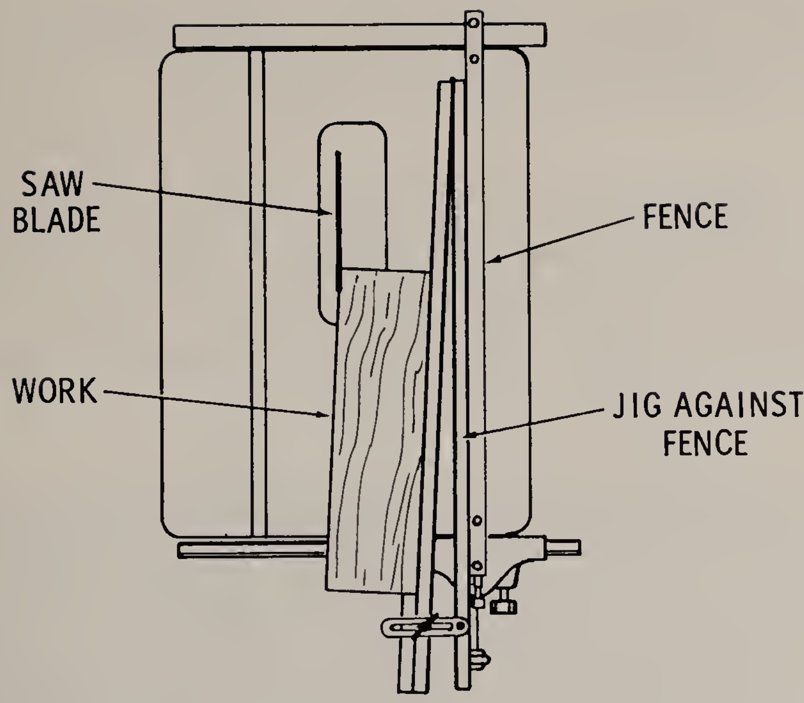


Fig. 26. Method of cutting taper on stock by means of tapering jig.

2. Lay out tenon on end of stock. Usually tenons are made one-half the thickness of the stock.

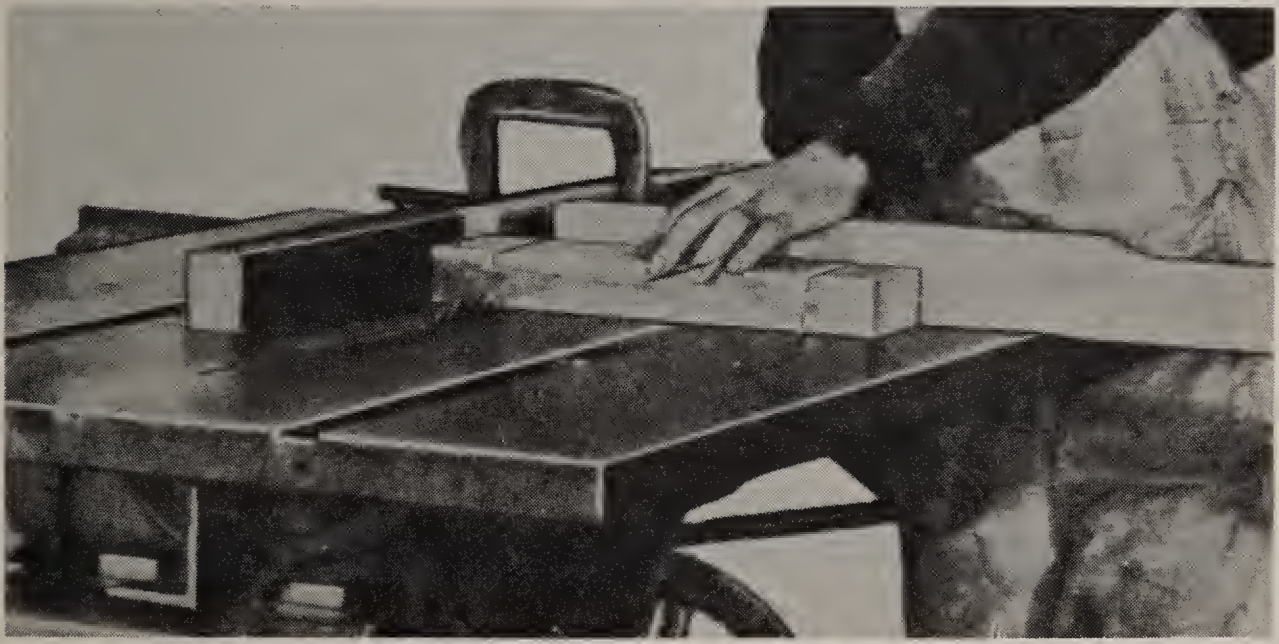


Fig. 27. Cutting shoulder of tenon, using clearance block on fence as a guide.

3. Raise or lower blade or table for correct depth of shoulder cut and clamp it securely.
4. Set the miter gauge at right angles to the blade.
5. Use the ripping fence, stop block, or clearance block to control the length of tenon as shown in Fig. 27.

Angled Shoulder Cuts—Tenons with shoulders cut at an angle may be produced by the circular saw in the following manner:

1. Fasten a miter gauge on each side of the saw blade at correct angle to give the desired shoulder cut. Make certain that both gauges are at exactly the same angle to insure that shoulder kerfs coincide with each other on opposite sides of each tenon.

Fig. 28. Method of cutting tenon cheeks using wood block to steady stock.

2. Attach a stop on each gauge, setting both stops at the same distance from the cutting edge of the saw blade.
3. Holding stock firmly against one of the miter gauges, cut first shoulder.
4. Move stock to the other miter gauge, keeping the same working edge against the miter gauge. Make the second shoulder cut.
5. Reset stops if necessary and cut tenons on the second end.

Using a ripsaw or combination blade, tenon cheek cuts are made as follows:

1. Remove the miter gauge.

2. Lay out cheek lines of the tenon carefully with a marking gauge, then adjust the fence so that the blade will cut along the cheek line.

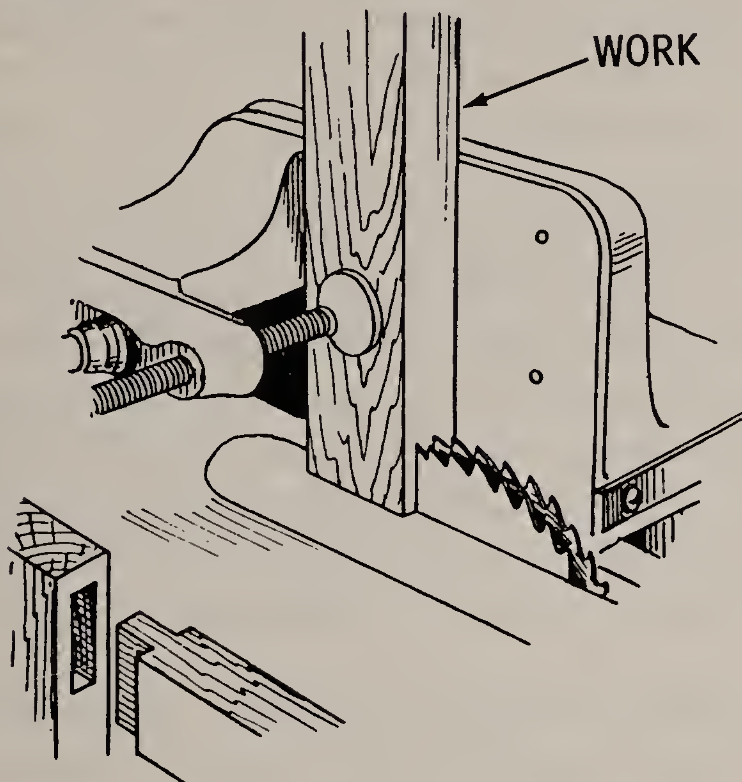


Fig. 29. Making cheek cuts with two saw blades and spacing collar.

3. Make the cheek cuts, guiding the stock with a suitable push stick. If the tenon has square shoulders, cut end of the push stick at right angles to the edge; if face shoulders are at an angle, cut end of push stick at the angle that will brace the stock in the correct position. Although not essential, a feather board fastened to table helps to hold stock securely against the fence and also protects the operator.
4. Generally, all work is done from the marked surface or edge. Either face or edge can, however, be held against the ripping fence if the stock is accurately dimensioned. If there is any doubt as to the uniformity in thickness of the stock, cut all work with the same working face against the fence, readjusting the fence for the second cheek cut.

Both cheek cuts can be made in one operation by using two blades at once as shown in Fig. 29. Mount both blades on the arbor with a spacing collar to hold them the correct distance apart. In determining the size of the collar, allow for set of the saw teeth,

otherwise the tenon will be too thin. Use paper or cardboard fillers for fine adjustments of spacing between blades.

Using Dado Head—The dado head may be used conveniently in cutting the cheek and shoulders of a tenon. Thickness and width of stock, however, must be uniform. To perform the cutting operation, proceed as follows:

1. Assemble the dado head as described and raise it above the table so that the depth of cut equals the amount of stock to be removed. Use sharp cutters in order to leave the bottom of the cut smooth. If possible use enough cutters so the width of the dado head equals the length of the tenon.
2. Clamp a stop block to the miter gauge to cut one side of the joint. Holding the stock against the miter gauge, use the ripping fence as a stop for cutting the other side of the joint.

Table-Extension Supports—When crosscutting or ripping long pieces of work, special supports such as shown in Fig. 30 are

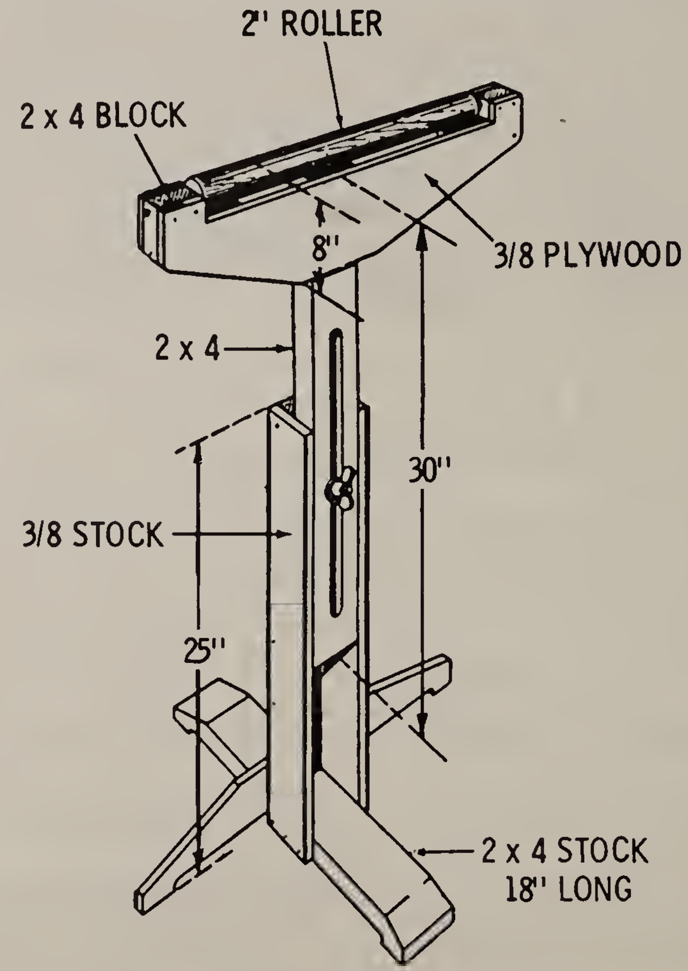


Fig. 30. Typical table-extension support. A support of this sort, while primarily intended for support when ripping long pieces of stock, may also be used to advantage when crosscutting long pieces.

commonly employed. As noted in the illustration, each one of the supports consists simply of an adjustable stand assembled of standard stock, topped with a hardwood roller to support and facilitate the movement of the work as it projects beyond the saw table.

When making a support such as shown in Fig. 30, sufficient adjustment allowance should be made to accommodate long work on the band saw and jointer as well as on the circular saw. Temporary outboard supports for long pieces of work may also be improvised by clamping a suitable board to the drill press or by fastening a hinged board to the wall at the correct height from the floor. Adjustable sawhorses, etc., are also used to support work which extends beyond the surface of the saw table.

CHAPTER 11

The Radial-Arm Saw

This type of saw is made in various sizes and differs from the universal and variety type mainly in that the saw moves on an overhead arm above the cutting table while the work remains stationary. The better type of radial-arm saw is provided with several accessories and adjustments to permit routing, dadoing, shaping, sanding, and saber sawing, as well as the conventional crosscutting and ripping. The chief advantage of the radial-arm saw over a table or portable saw is that it takes up a comparatively small amount of space in the shop while enabling the operator to do numerous woodworking jobs which normally would require several machines.

Crosscutting—Another advantage of a saw of this type is the minimum of movement and the ease of crosscutting. The work is set on the horizontal table so that it is in line with the saw blade (Fig. 1). The head assembly is pulled forward, and the cut is made accurately without any movement of the work. The depth of the cut is adjusted by raising or lowering the head assembly. The cut will always be square, and there is no need to mark the material with a hand square prior to sawing.

To obtain 90-degree cuts, provisions are made for minute adjustments so that the saw blade can be kept accurately aligned throughout its entire service. When making the cut do not allow the saw blade to pass through the work too rapidly. Never attempt a cut by pushing the saw blade through the work. To cut stock which is wider than the maximum travel of the saw, the work can be turned over 180 degrees to complete the cut.

Bevel Crosscutting—Bevel crosscutting is similar to crosscutting, except that the motor is tilted to the desired angle, as in-

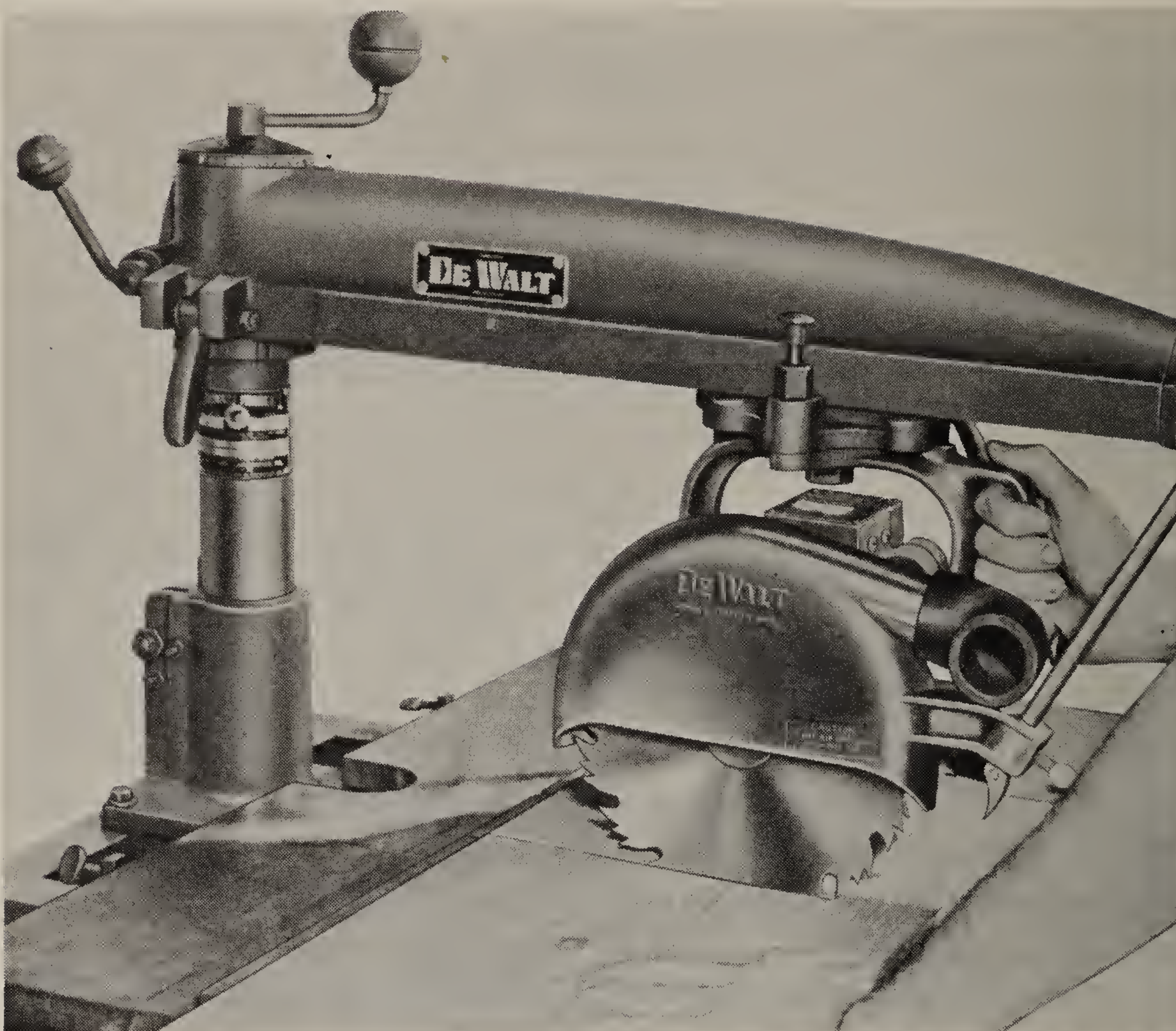


Fig. 1. Crosscutting with the radial-arm saw. When crosscutting, the arm must be at right angles with the fence, indicated by 0° on the miter scale. First, locate miter latch in the column slot at 0° position, then accurately lock arm with arm-clamp handle. Place material on worktable against fence and draw the saw blade across for the cut. After completing the cut, return the saw blade behind the fence, then continue this routine for successive straight crosscuts.

dicated on the scale, and locked in place. The bevel latch locates the 45- and 90-degree positions, and if any other angle is desired, the bevel clamp can be used to hold the motor rigidly in position. Lower the column enough to ascertain that the blade cuts through the material and proceed in the same manner as when crosscutting.

Mitering—Mitering and angular cutting are performed in a similar manner to crosscutting but with the radial arm set to the desired angle. There is no need to measure the degree of miter; simply position the arm to the correct angle as indicated on the scale. The arm-clamp handle is employed to position the radial arm at any angle less than 90 degrees.

Compound Mitering—Compound miter cuts are combined

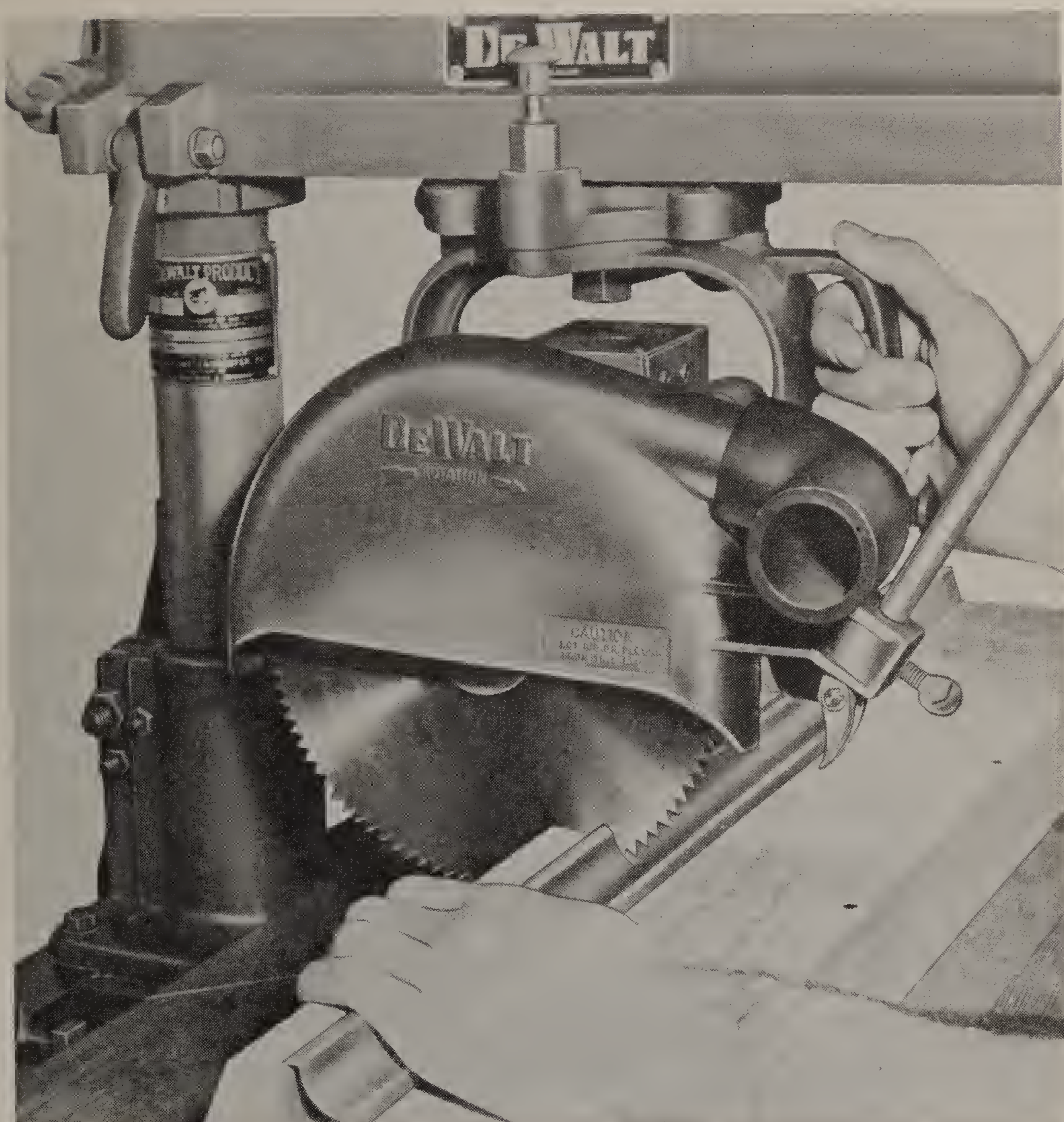


Fig. 2. Cutting molding with the radial-arm saw.

bevel and miter cuts. To cut a compound miter, set up the machine for bevel cutoff. Release the arm latch and the clamp handle, and swing the arm into the desired miter position. The angle can be read directly from the angle scale on the indexing bracket. Follow the normal crosscutting routine. Bring the saw blade across the material steadily without undue pressure.

Straight Ripping—Straight ripping is second only to crosscutting in frequency of use, and this operation is accurately and easily performed on the radial-arm saw. For ripping, the arm must be clamped in the crosscut position. Pull the entire motor carriage

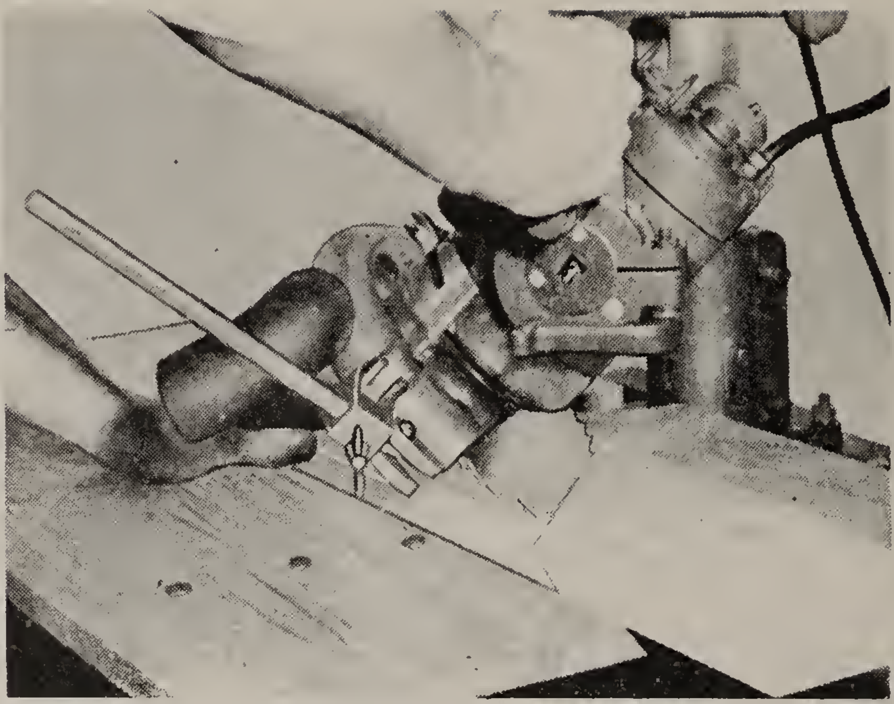


Fig. 3. Compound miter cut with the radial-arm saw. To make a compound miter cut, the saw must be first set for bevel cutoff. Then release the arm latch and the clamp handle and swing the arm into the desired mitering position, following the same routine as for making miter cuts. Follow normal operating procedure as described under crosscutting.

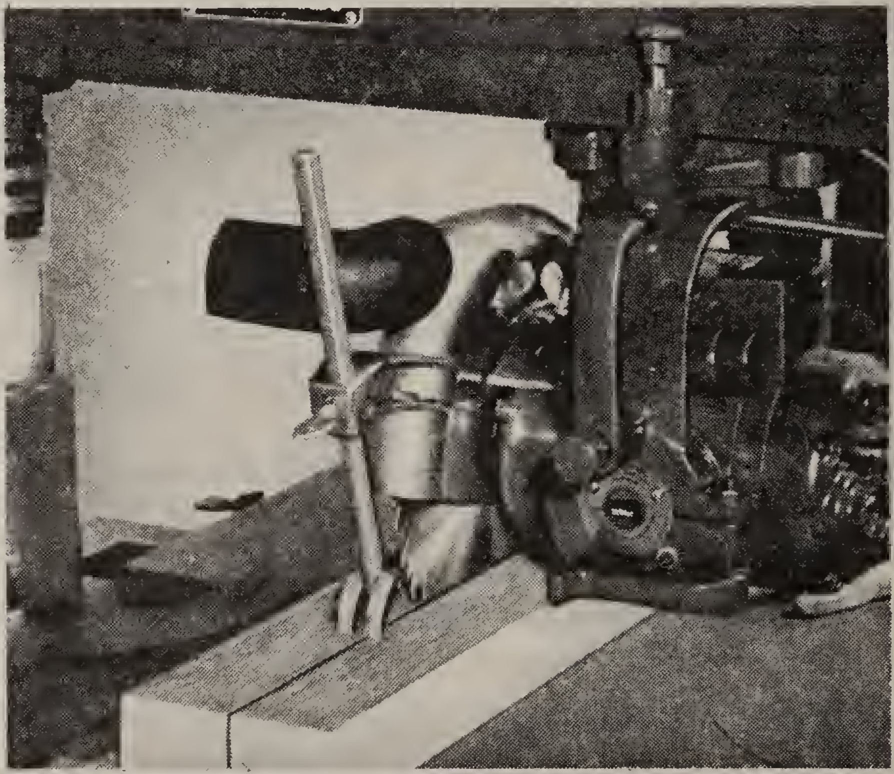


Fig. 4. Straight ripping with the radial-arm saw.

to the front of the arm, lift the rip latch, release the swivel-clamp handle, and revolve the motor yoke under its carriage.

Position the carriage on the arm to the desired width of the ripping cut. The safety guard is lowered to within touching distance of the material to protect the operator from the moving blade.

A special antikickback device, when lowered into position, insures that the stock will not be thrown back by the ripping motion of the blade.

When ripping, keep the material against the fence and feed it evenly into the saw blade. Always stand at the front side of the saw blade, never back of it. When ripping stock into narrow strips, the use of a push stick is advisable because the stock may not be wide enough to safely accommodate the hand.

Tapered Ripping—Tapered ripping on the radial-arm saw is performed by using a special, tapered pusher board between the guide fence and the stock. This operation is performed with the machine in ordinary ripping position. Many craftsmen find the uniform taper obtained by this cut very useful in the making of

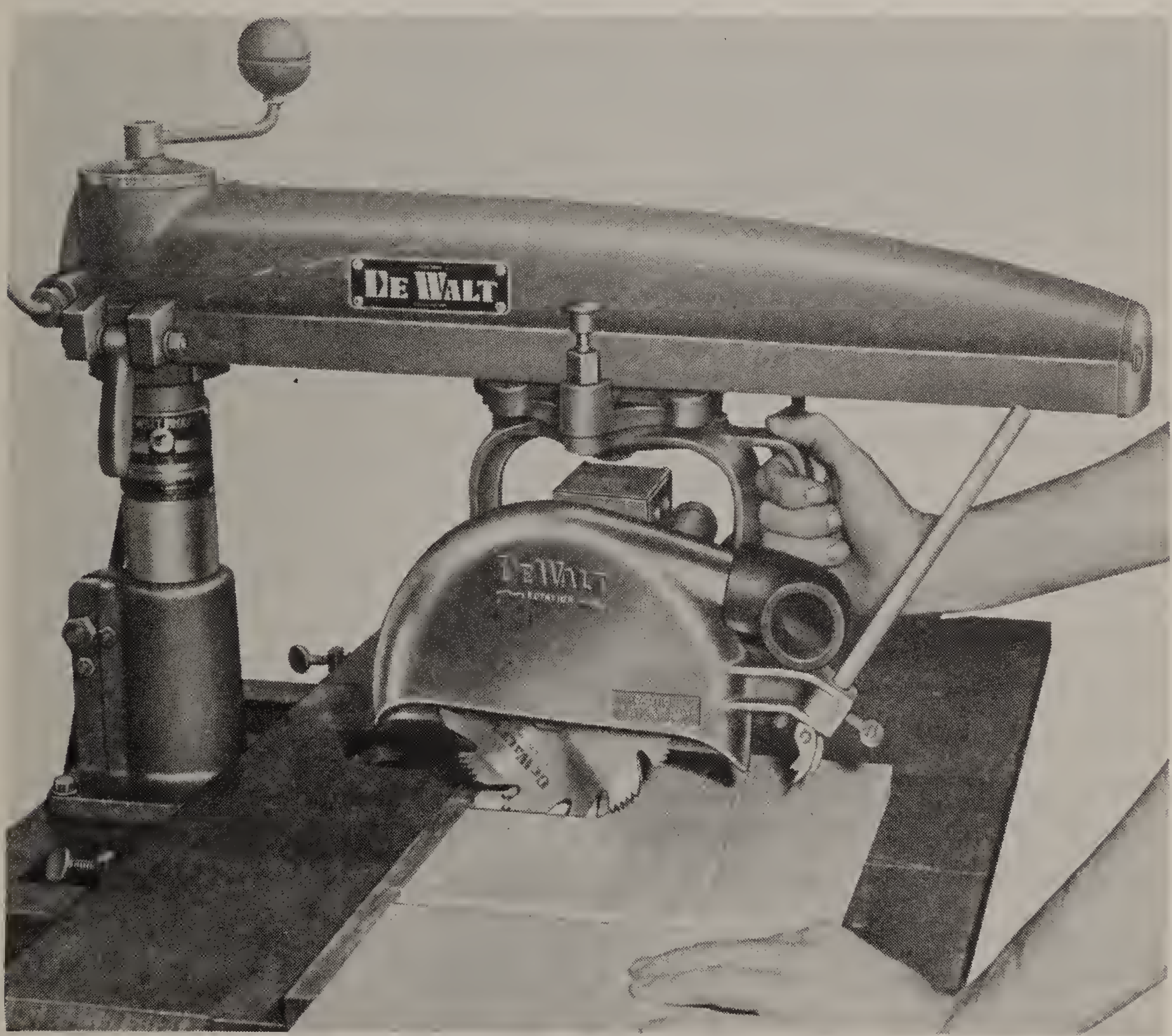


Fig. 5. Typical dadoing operation with the radial-arm saw. It should be noted that any width of cut can be made by making a series of similar cuts exactly parallel to one another. Dado cuts of the type illustrated are widely used in grooving for shelves, drawers, etc.

table legs for both modern and colonial furniture. Long wedges and stakes can also be produced in this manner.

Bevel Ripping—Bevel ripping is similar to straight ripping except that the saw blade is tilted to any desired degree of bevel as indicated on the bevel scale. Adjust the guard on the infeed end so that it almost touches the material to be cut, but do not adjust the antikickback device. Always give the saw blade a chance to cut, hence feed it steadily for best cutting results.

Dadoing—For dadoing on the radial-arm saw, remove the blade from the motor arbor and mount the dado-head adapter in its place. For best results, the two outside cutters should be arranged so that the large raker teeth on one blade are opposite the small cutting teeth on the other blade. Be sure also that the teeth of the inside cutters are placed in the gullets of the outside blades, not against the teeth. Also stagger the inside cutters so that their teeth do not come together.

The dado head is operated in the same way as the circular blade, but the operation is somewhat slower because of the increased amount of material to be removed from the work. Therefore, the wider and deeper the cut, the slower the work should be fed. Straight dadoes are cut by using the crosscutting procedure, and angle dadoes are cut by using the mitering procedure. Make wide cuts by moving the dado head back and forth over the material. The dado head can be operated in either direction.

Plowing—The plowing operation with a dado head corresponds to the rip cut with a saw blade. Thus, to plow, replace the blade with the dado head, in the manner previously described. Place the dado head in the desired position, clamp the rip lock on the arm, and lower the dado head to the desired depth. Adjust safety guard so that the infeed end almost touches the material, then set the antikickback device on the opposite end. Feed the material carefully and steadily, holding it tightly against the fence.

Center or blind plowing is accomplished by raising the column until the stock to be cut will slide beneath the dado head. Then lower the moving dado head into the lumber to the desired depth and at the start of the cut.

Bevel plowing is accomplished with the radial arm and the yoke

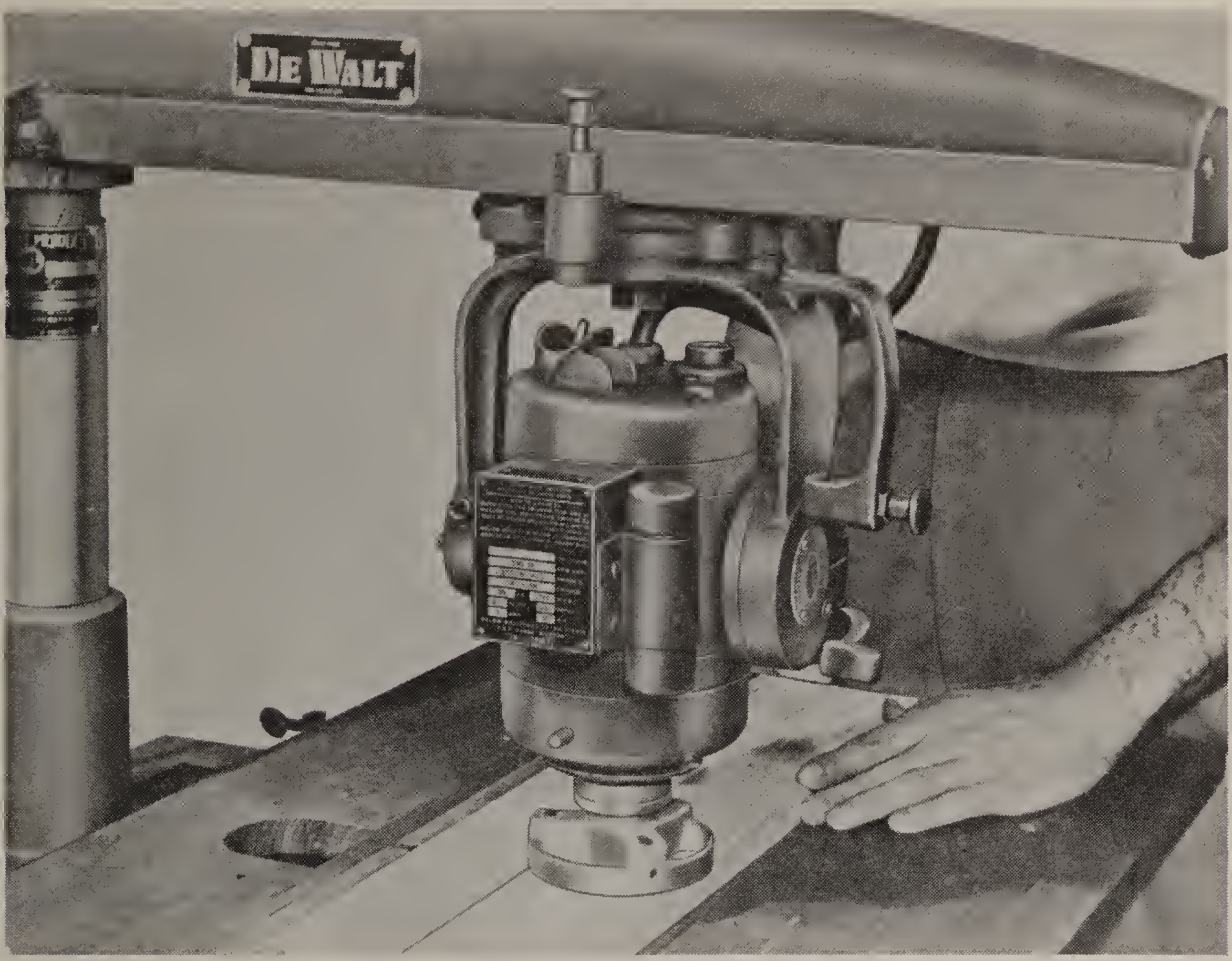


Fig. 6. Planing operation with the radial-arm saw.

in the same position as for straight plowing. In this position, however, the motor is tilted to a 45-degree position. Bevel plowing leaves a smooth, accurate vee-groove in the stock. It has many applications, both functional and decorative, in cabinetmaking and general woodworking.

Rabbeting—Rabbet cuts with a dado head employ the same setup as that previously described for plowing. Release the bevel latch and clamp, and raise the column until the motor is in the correct vertical position with the blade horizontal. Clamp the carriage securely in the 90-degree slot and lower the dado head to the desired depth. The work may have to be blocked up so that the motor shaft will not hit the table. Move the carriage to the front of the guide fence for the width desired. Hold the work firmly against the guide fence and table surface, making the cut in one smooth, steady, continuous operation.

Tenoning—To cut tenons, insert spacing collars between the dado blades and set the motor as for rabbeting. Use a wider guide

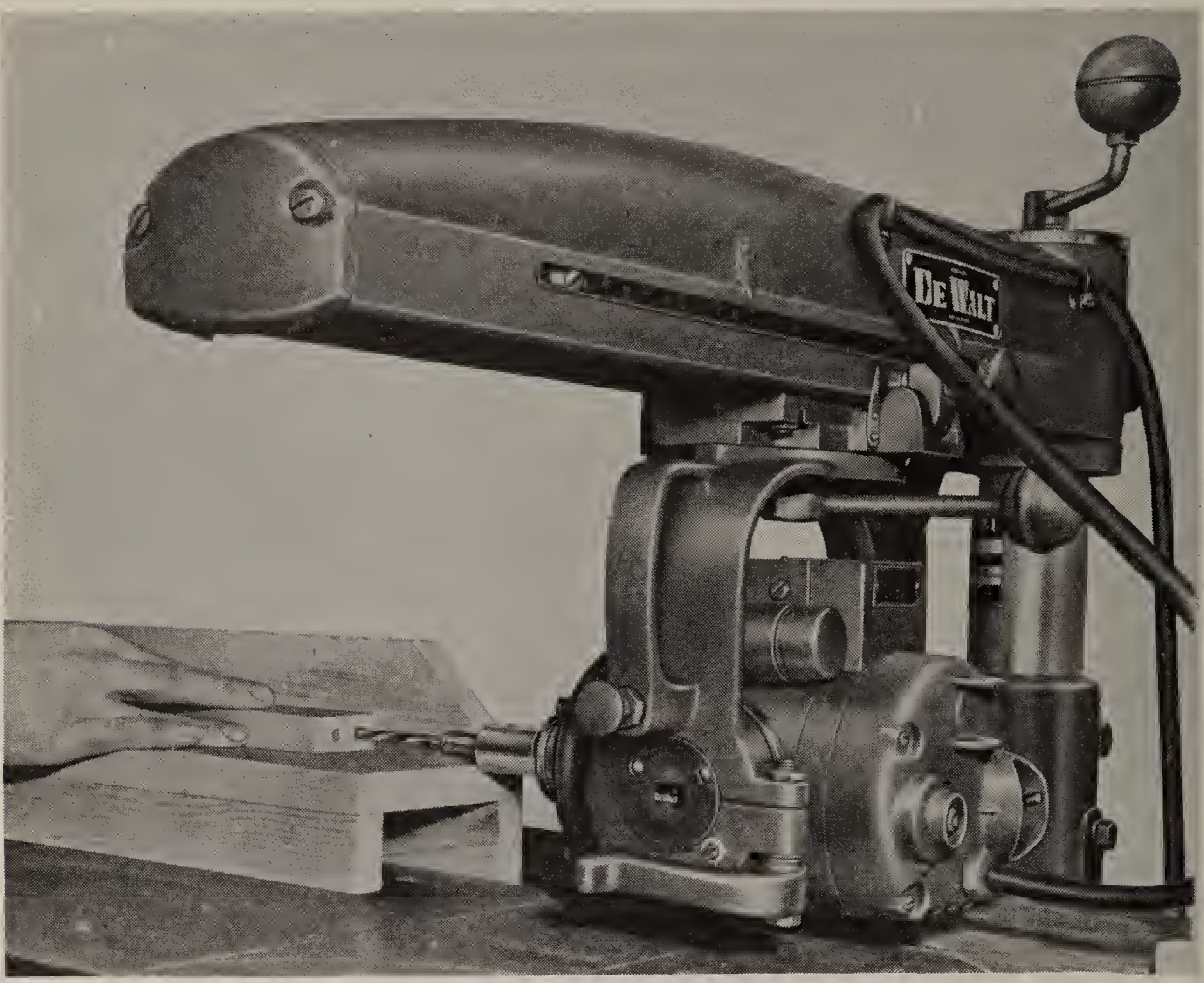


Fig. 7. Typical boring operations with the radial-arm saw.

fence so that it projects about three inches above the table top. Pull the tenon cutters forward in front of the guide fence to obtain the desired cut. Use a push stick to feed the stock past the cutters. Making an open-end mortise consists simply of cutting a groove to the same width as a previously made tenon.

Radius Cutting—This is a dado operation used to produce a concave cut along the face of a piece of lumber. It is accomplished by elevating the column (radial arm and yoke remain in normal crosscut position) and dropping the motor to the 45-degree bevel position. The carriage is moved in or out on the radial arm to the correct position in relation to the stock to be cut and locked in place. The lumber is then pushed under the cutting head as when ripping or plowing.

Shaping and Routing—To do shaping on a radial-arm saw, the blade is removed and a three-jaw chuck or cutterhead is attached to the arbor in the usual manner. The motor should be in the same vertical position as for rabbeting. Vertical and horizontal

adjustments on the machine permit any part of the shaper cutter to be used. Adjust the machine so that the desired form or shape is profiled on the edge of the material. Lock the motor carriage by securing the rip lock on the arm. For best results, feed the material into the shaper cutter steadily, against the guide fence and with the grain.

For routing, remove the blade and place a router bit on the motor shaft. Place the machine in the same position as for the shaping operation. Move the guard fence toward the rear of the worktable for more working space. Lower the router bit into the material by turning the column elevating handle. Lock the router bit in one position by securing the rip lock on the arm. Freehand routing may be accomplished by moving either the material or the bit. When using the latter method, nail the material to the worktable, release the rip lock and move the router bit by swinging the arm and moving the motor carriage as necessary. Templates can also be used.

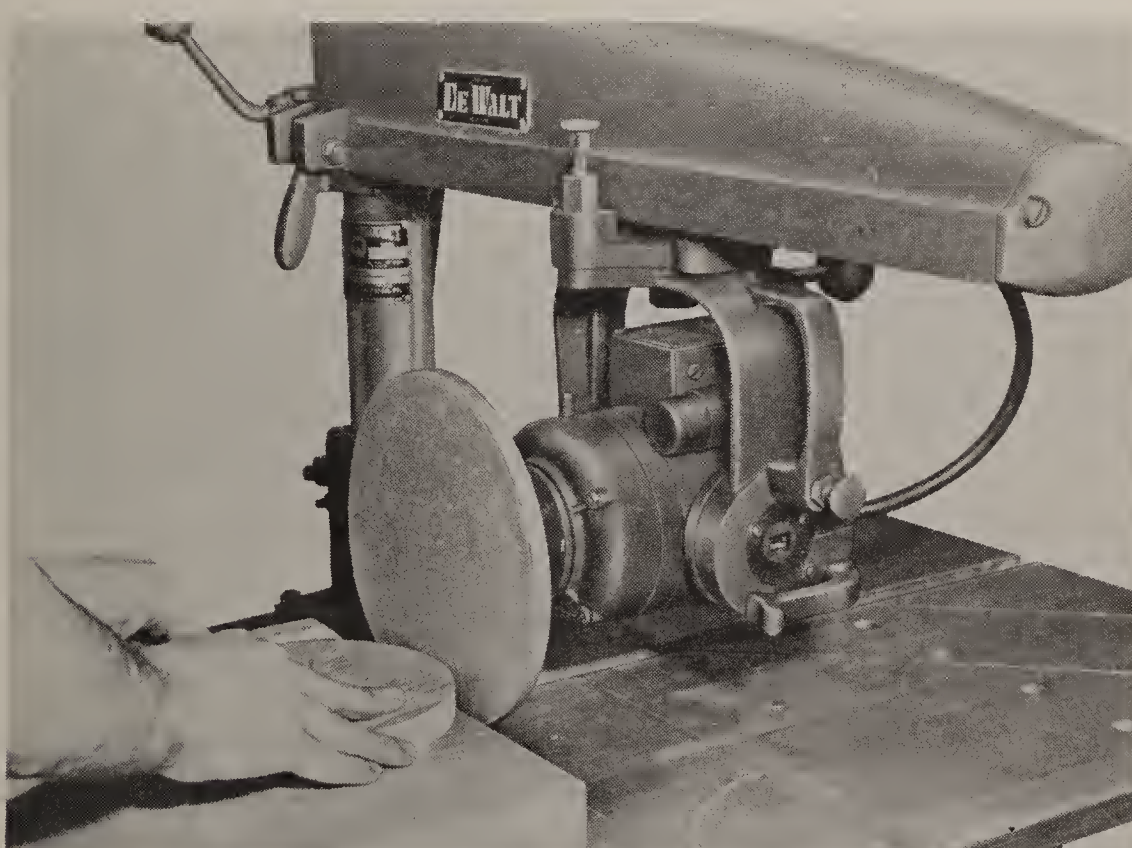


Fig. 8. Typical sanding operations with the radial-arm saw. For making perfect circular objects such as table tops, start with a perfectly square board; find the exact center and mark it; then cut the square down until it is roughly circular. Drive a nail through the center mark to hold the material to the jig. Then slowly rotate the board (moving it closer to the sanding disk from time to time) until it is perfectly round and uniformly smooth.

Boring—Various types of boring operations in wood may also be performed on the radial-arm saw by mounting special adapters and boring bits on the motor shaft. Boring may be performed with the bit either in a vertical or horizontal position, although when holes of great depth are desired, the boring is commonly done in the horizontal position, because the depth of the hole will then be limited only by the length of the bit itself.

Miscellaneous Operations—By using a variety of attachments, drilling, disk and drum sanding, rafter notching, etc., may also be performed on the radial-arm saw. By boring a small hole through the table and mounting an adapter on the motor bracket, the rotary motion of the motor shaft is converted into a reciprocating movement for saber-saw use. Thus, any job usually delegated to the saber saw may also be easily and efficiently accomplished on the radial-arm saw.

CHAPTER 12

The Band Saw

Band saws are manufactured for a large variety of uses. For ripping and resawing, large machines with blades three to five inches wide are generally used. The type most adaptable to the general workshop is the band saw having blades from ¼ to 1 inch wide and used particularly for cutting curved outlines and lines not parallel to an edge of the piece being cut.

Essentially, a band saw consists of a table, wheels, guides, saw blade, and suitable guards. On most of the larger machines, the table can be tilted, usually 45 degrees one way and 10 degrees the other. Some, however, are built to permit bevel cutting by varying the blade angle. The band saw is generally used for resawing because of its thinner kerf.

Construction—A band saw (Fig. 1) such as is used in woodworking shops consists generally of an endless band of steel, with saw teeth on one edge, passing over two vertical wheels and through a slot in a table. The blade is held in position for the thrust of the wood against the teeth by two guides.

The two vertical wheels over which the blade is fitted are usually made of cast iron, and their rims are coated with rubber. The wheels are provided with adjustments for centering the saw upon the rims and for giving the saw blade the proper tension. The table supporting the work is fastened to a casting directly above the lower wheel. It is slotted for the saw blade from the center to one edge. To prevent the blade from twisting sideways in the slot and to give it support when cutting, the band saw is provided with guides, the design of which varies for different types of saws. Some tables are equipped with a ripping fence and some are also provided with a groove for a miter gauge.

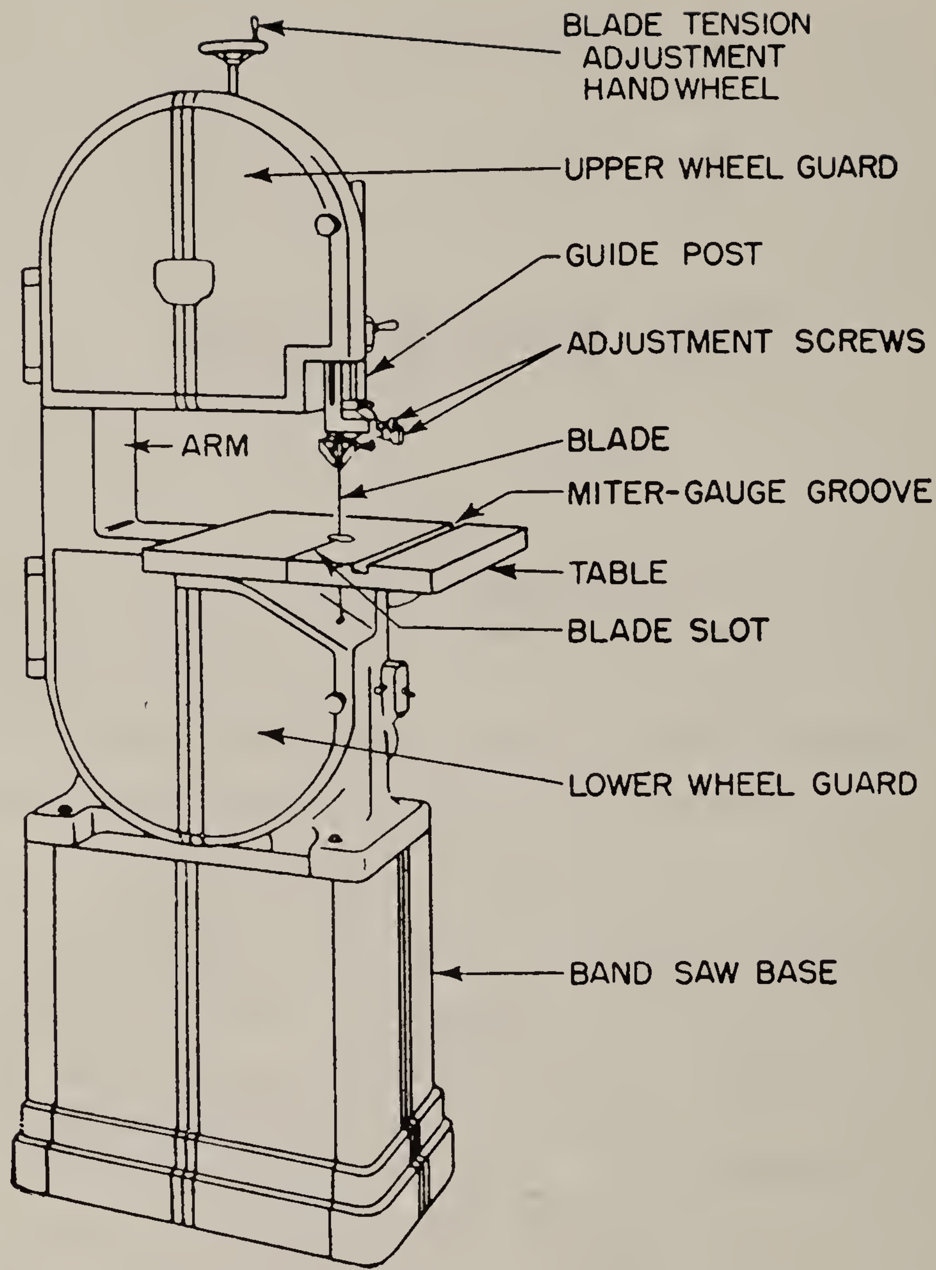


Fig. 1. A typical 14-inch band saw suitable for the small- and medium-sized woodworking shop. Tension and tilt are regulated by a convenient handwheel and a knob. The blade guides are designed to provide maximum support to the work, with the blade fully shielded for safety. The wheels are dynamically balanced and the upper wheel unit rides on two heavy ground steel rods with a spring cushion to absorb blade shock. The blade speed of the saw illustrated is 2,535 surface feet per minute with a 1,750 rpm motor.

The size of the band saw depends upon the diameter of the wheels, which may vary in size from 10 to 40 inches approximately. Thus, a saw having 10-inch wheels would be called a 10-inch band saw. Of course, the larger the wheels, the larger in proportion are all the other parts of the saw, and larger size stock can be sawed. Other important dimensions of the band saw are the table size and the height between the table and the upper blade guide.

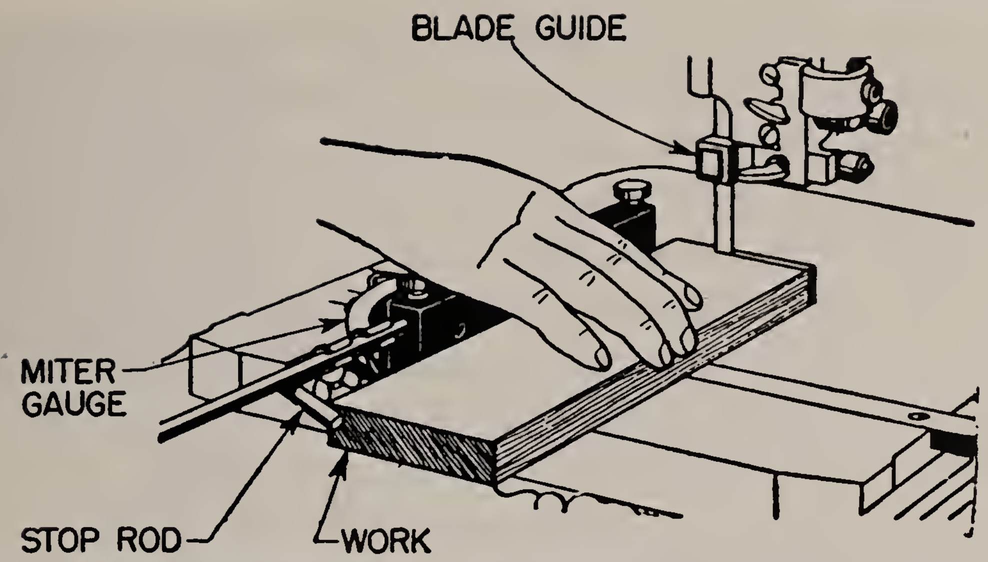


Fig. 2. Cutting to length with a miter gauge and stop rod. The stop rod should be carried on the outer end of the miter gauge.

Straight-Cutting Operation—Although a band saw is essential for curved cutting, it may also be used for making straight cuts for both crosscutting and ripping, when a circular saw is not available. For all straight cuts it is advisable to use the widest possible blade because it is easier to follow a straight line with a wide blade. The use of the miter gauge in crosscutting wide stock follows the same general procedure as that used for similar work on the circular saw. In the absence of a miter gauge, a wide board with square ends and sides may be used.

The use of an auxiliary wood fence fastened to the miter gauge will facilitate the handling of large boards and will result in more

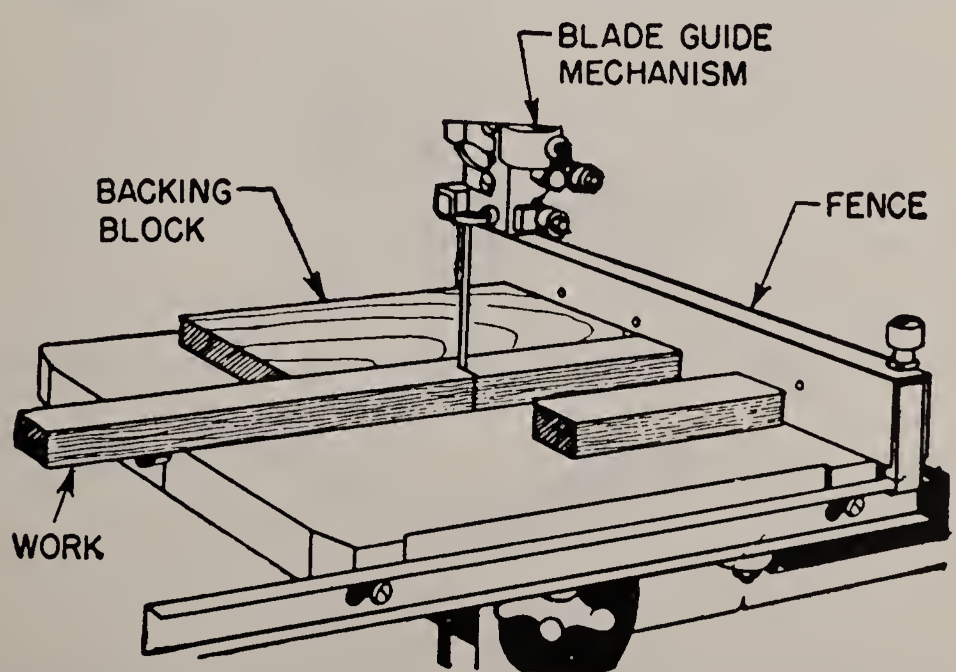


Fig. 3. Method of cutting short pieces to length using square board or ripping fence, when the miter gauge is not available.

accurate work. Unlike the auxiliary ripping fence for the circular saw, the auxiliary ripping face for the band saw should be kept low, so that it will work under the guides. Ripping and resawing may be performed on a band saw by the use of the ripping fence furnished with most saws. When the stock is worked flat on the table, the operation is known as *ripping*, and when the board is worked on edge the operation is usually known as *resawing*.

Cutting Circular Arcs and Segments—In cutting circular arcs, the usual procedure is to make an outline by means of a compass or divider after determining the correct radius. If several pieces all having the same curvature are to be sawed, a jig may preferably be made, in which case the circular arcs can be accurately cut without first marking the outline.

Multiple-Sawing Operation—To secure maximum output on band-sawed work, it is necessary to use an up-to-date machine, securely mounted on a substantial foundation to eliminate vibration. The blades are the next important part of the equipment and need to be kept in prime condition and properly adjusted on the wheels. When a considerable amount of wood is to be processed, an extension to the saw table is a real convenience.

The numerous furniture parts which are frequently sawed in multiple-sawing include ornate chair and table stretchers, chair bannisters, radio-cabinet grilles, small brackets, etc. The grilles

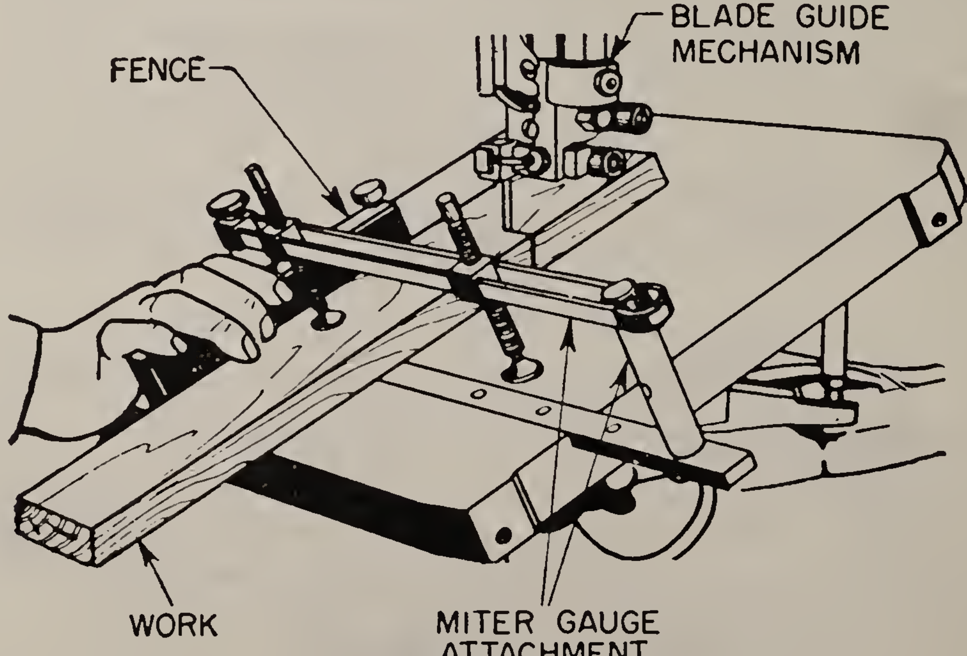


Fig. 4. Use of the miter-gauge clamp attachment. An attachment of this type is useful in many crosscutting operations and particularly when cutting at an angle with the table tilted.

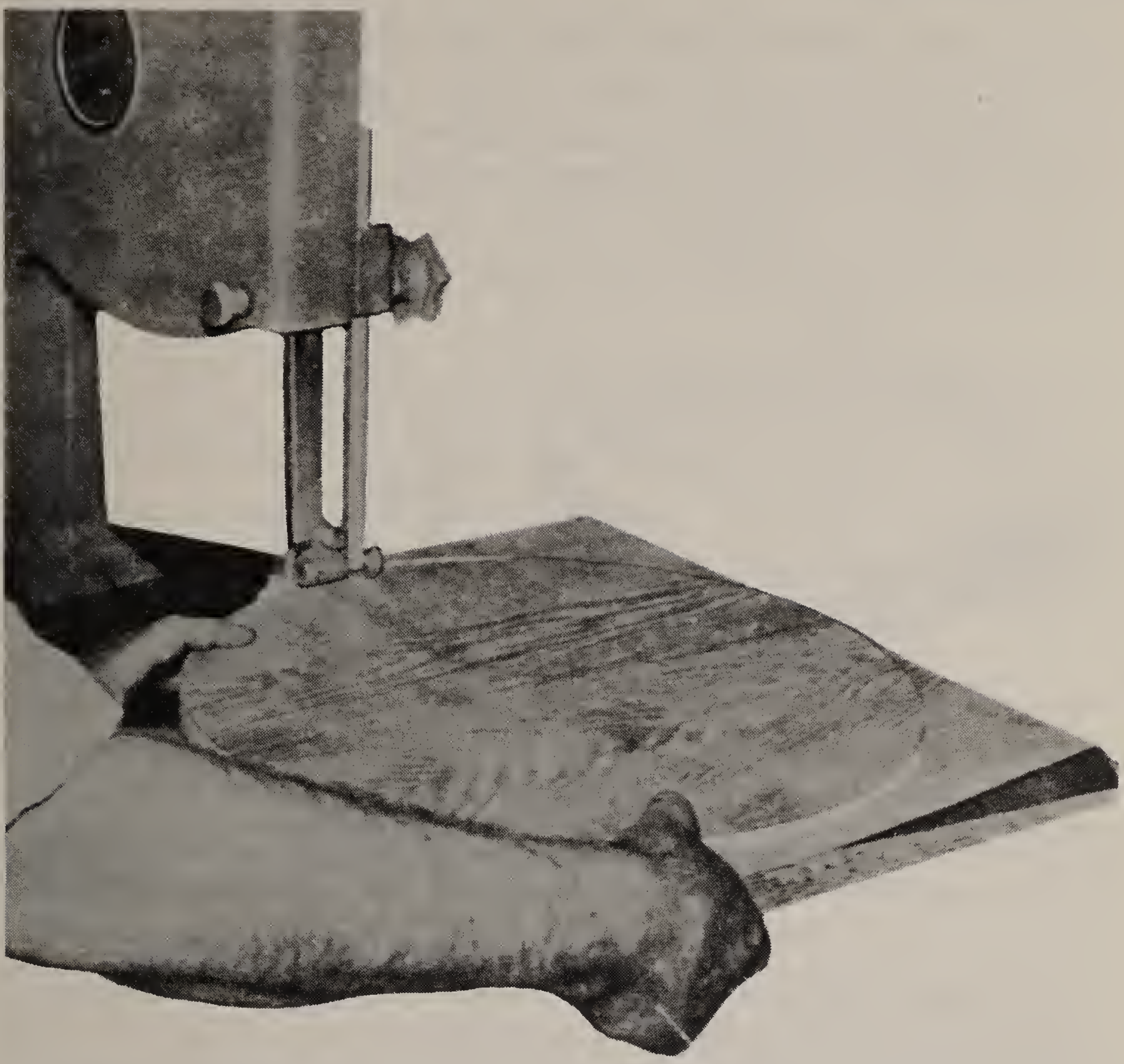


Fig. 5. Method of cutting a circular disk on the band saw.

and similar items are usually scrolled on a jigsaw. Dependable machines are usually provided with accurate tension devices which assist the operator in securing volume production as well as turning out high-class work. Some present-day jigsaws are constructed with the table and saw guides set at such an angle with reference to the machine column that extremely long material may be sawed easily.

When cutting certain classes of thick material, best results may be obtained by sawing one piece at a time, particularly where there are pitch spots and checks and knots to be dodged. On the other hand, anywhere from 8 to 18 pieces of veneer or thin plywood can often be scrolled simultaneously, depending on the thickness of the stock. Some favor the idea of tacking pieces together lightly before sawing, but a more satisfactory system is to cut two or

more ¾-inch slits in their edges after stacking them up evenly on the saw table. A hardwood wedge driven into each of these slits will serve to hold the stock together while being processed. It is not unusual to find workmen scrolling eight or more pieces of

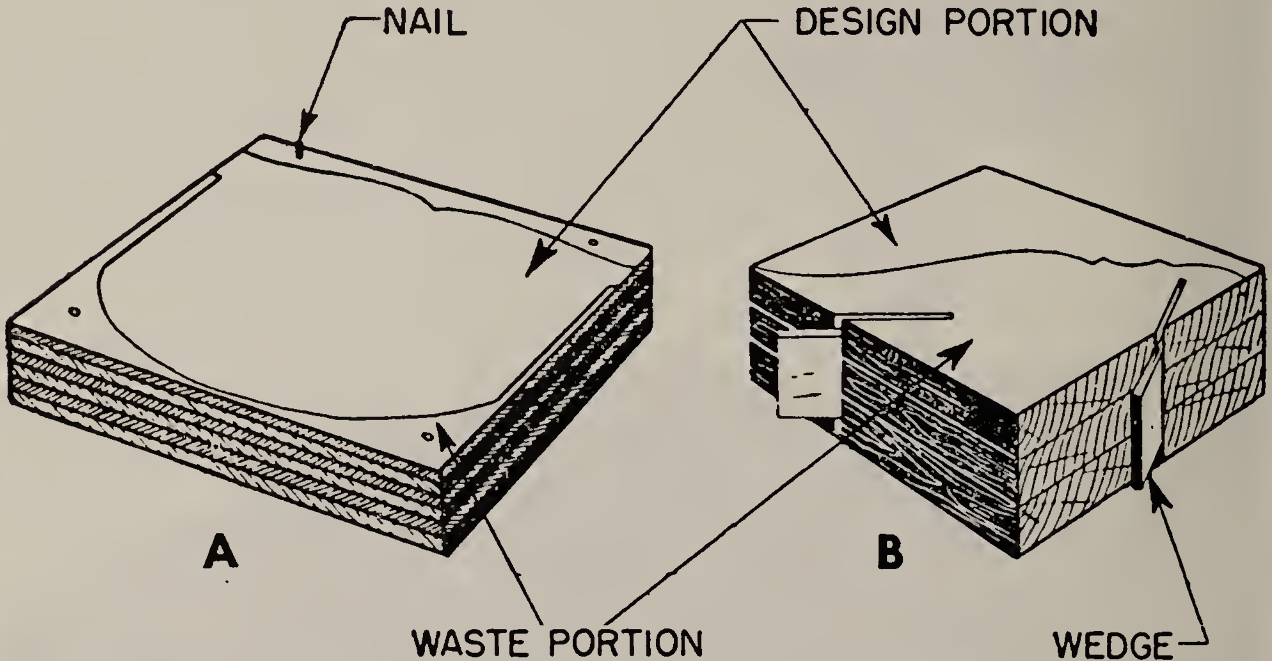


Fig. 6. Method of assembly in multiple-sawing operations. (A) Nails are driven into the waste portions of the design to hold the parts together while being sawed. (B) Multiple-sawing operations with stock wedged together.

¼-inch plywood at one time without fastening plies together in some manner. This calls for considerable dexterity and it is really not advisable to attempt it on work where great accuracy is essential unless the workman is an expert.

Pointers on Band-Saw Operation—In order to obtain the maximum quantity as well as the best possible quality from the band saw, it is necessary that the operator understand its operation and be able to adjust it properly. Prior to the actual sawing it is necessary that the operator be carefully instructed in the various safety features with which the band saw is equipped. He should be familiar with the removal of the wheel guards and, before operating the band saw, should make certain that they are securely fastened. Some band saws are equipped with a braking device whereby the drive may be stopped quickly for blade changes. One type is provided with an automatic brake which instantly stops the wheels should the blade break.

Emphasis should be placed on the fact that the widest blade possible should be used, giving consideration to the minimum

radius to be cut on a particular class of work. A rule of thumb used by many is that the width of the blade should be one-eighth the minimum radius to be cut. Thus if the part on hand has a 4-inch radius the operator would select a ½-inch blade. This rule should not be construed to mean that the minimum radius which can be cut is eight times the width of the blade, but rather that such a ratio indicates the practical limit for high-speed band-saw work.

Probably the most frequent cause of difficulty in obtaining good results with the band saw is misalignment of the blade guides. There are several styles of guides available, each of which has certain advantages. Most have a hardened steel disk mounted on a ball bearing to serve as a support to the back of the blade. The purpose of the back guide is to hold the blade as the work is being cut and prevent it from being pushed from the wheels.

When the saw blade is properly tracked on the wheels, the back guide will not be in contact with the blade. If it is in constant contact with the back support, the resulting friction will in time cause the back edge of the blade to become case-hardened. Such a blade with unequal tension throughout its width is susceptible to fractures and breakage. A blade in contact with the back guide wheel when it is not cutting also indicates that there is excessive tilt in the upper wheel, which will cause too much bearing wear.

In addition to the back support wheel, the band saw is equipped with two side pressure guides which prevent the blade from twisting as the work is cut. These are either square pieces of hardened tool steel or rollers.

The square tool-steel type is most common and should be set so that the teeth are slightly forward from the guide pins, so the blade will not be dulled and the set removed from the teeth by contact with the guides. The proper clearance between the side guides and the blade can be measured by placing a piece of paper between them when adjusting. When the guides are properly set, the blade will not touch them while the saw is running under no load. This requires perfect alignment between upper and lower guide sets. When correctly adjusted there should be 1/64-inch clearance between the blade and all guides.

Another type of band-saw guide which has come into limited use during the past few years is pivoted on a yoke arrangement

so that it allows the blade to twist in following curves. Such an arrangement, it is felt, allows more rapid and accurate cutting of curved sections with less effort than required where the conventional type of guide is used.

The problem of obtaining correct blade tension is difficult for inexperienced operators on band saws not equipped with a tension gauge. Several band saws have tension scales which are calibrated to show correct tension for each of the various width saw blades. When the saw is not so equipped, the operator must learn to adjust the blade tension by "feel." One method of testing blades ½ inch and narrower is to raise the upper guide and place the first and fourth fingers on one side of the blade and push the blade with the thumb on the opposite side. If the blade can be deflected slightly, the tension is about right, but if the blade cannot be flexed, it is tensioned too tightly.

On blades wider than ½ inch, the blade should flex about ⅛ inch for proper tensioning with the upper guide raised 12 inches above the lower guide.

Where the band saw is operated continuously, the tension may have to be increased gradually, because the heat of the blade will cause it to expand and stretch. As the blade expands, tension will decrease and cutting will become more difficult. At the end of the day's work, the blade tension should be relieved, because the blade will contract as it cools and may fracture if the tension is too great.

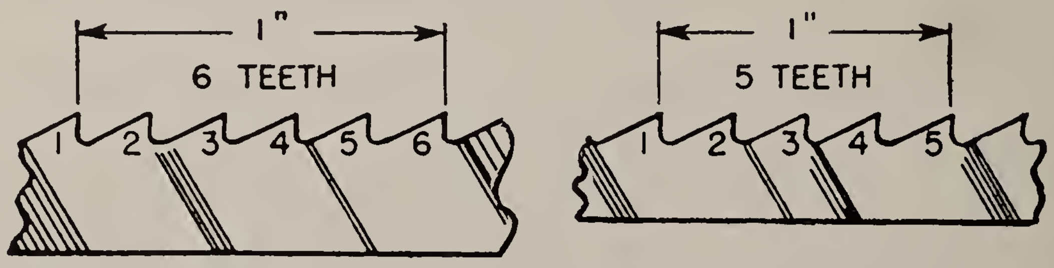


Fig. 7. Method of designating number of teeth to the inch.

Since smooth band-saw operation depends on proper adjustment of the guides and proper tensioning and tracking of the blade, the operator who does not understand how to adjust the band saw cannot be expected to turn out first-class work. The operator should also be able to select the correct blade for the class of work at hand. As previously mentioned, the widest blade possible should

be used, taking into consideration the radius of curves to be cut. On straight or gently curving portions of the work, it is much easier to follow the contour with a wide blade because narrow blades often have a tendency to wander.

Band-saw blades are commonly classified as 4-, 5-, 6-, or 7-tooth blades. This designation refers to the number of teeth per inch of blade length. Where smooth cuts are desired, the 6- or 7-tooth variety should be used. Where speed is of more importance than the smoothness of a cut, a 4-tooth blade should be employed, because its larger teeth will cut more rapidly.

CHAPTER 13

The Jigsaw

The jigsaw differs radically in construction from the band saw although the type of work for which it is designed is very similar. The jigsaw is more adaptable than the band saw for cutting small, sharp curves because much smaller and finer blades may be used. Inside cutting is also better accomplished on the jigsaw, since the blade is easily removed and inserted through the entrance hole bored in the stock.

Construction—The jigsaw consists essentially of a *base* or *frame*, *driving mechanism*, *guides* and *saw blade*. The driving mechanism has a motor-driven wheel which is connected by a steel rod to a bar, termed the "crosshead," which moves up and down between two vertical slides. This arrangement converts the rotating motion of the motor into a reciprocating (up-and-down) movement of the blade.

The table built around the blade is usually designed for tilting at an angle of up to 45 degrees. The size of the jigsaw is generally expressed in terms of the throat opening—that is, the distance from the blade to the edge of the supporting arm. The distinguishing feature of saws of this type, as previously noted, is that the blade moves with a reciprocating motion instead of continuously in one direction as in the case of circular saws and band saws. Accordingly, one-half of the distance traveled by the saw blade is effective in cutting.

With the jigsaw and its numerous attachments, there are comparatively few cutting operations that can not be accomplished readily. Its primary uses are for cutting intricate curves, corners, etc., as in wall shelves, brackets and novelties of wood, metal and plastics.

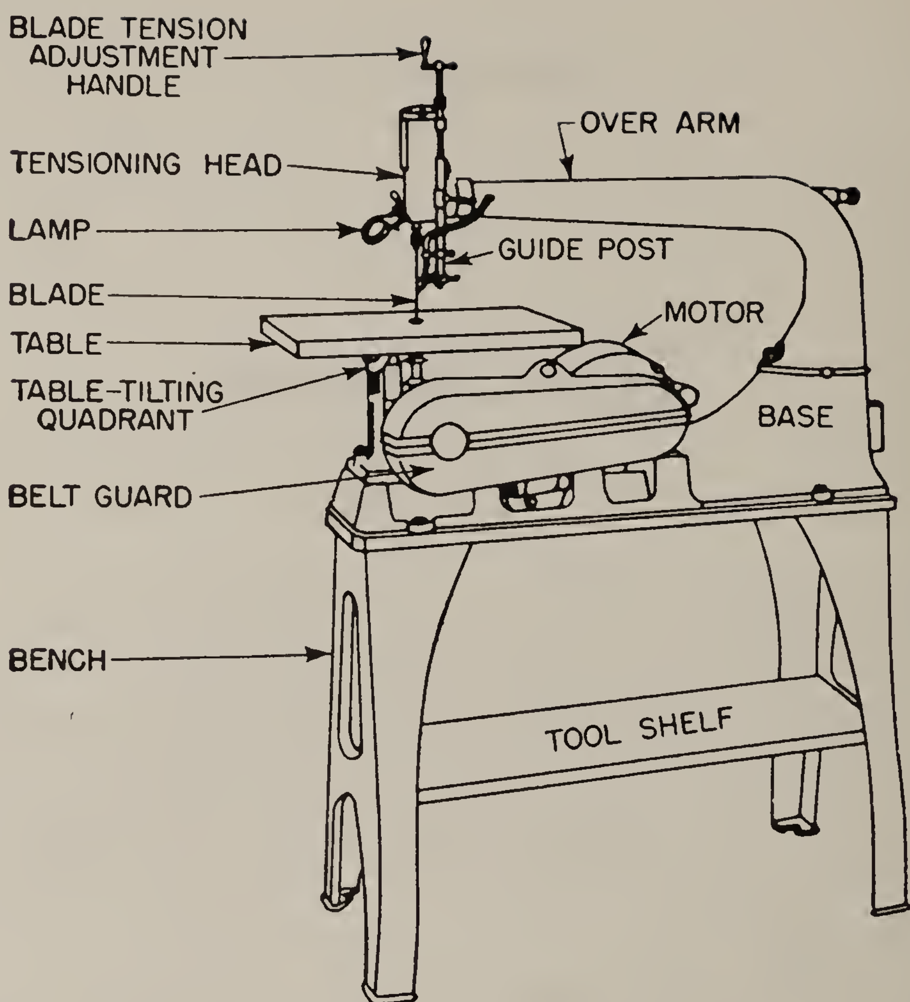


Fig. 1. Component parts of a typical jigsaw. A jigsaw of this type uses a standard six-inch blade, but can accommodate any blade from 5 to 15 inches because of hollow vises and shafts. The cast-iron table can be tilted 45 degrees either way and is equipped with a graduated quadrant showing the exact number of degrees of tilt. The upper head adjusts on dovetail ways by means of a hand crank and knurled locknut. Blade tension is shown on a scale, and may be regulated for minimum vibration while the machine is running. The drive mechanism is of the reciprocating type with link and counterbalanced crank. The air pump is powered by the main drive shaft and keeps the cutting line clear at all speeds of the saw. The guides are completely adjustable for front and side sawing and are equipped with a soft refaceable blade support and a ring-type hold-down device.

Jigsaw Operation—As previously mentioned, the jigsaw is used primarily for making various types of intricate cuttings on work which cannot be made readily on the band saw. The chucks are generally made to accommodate various sizes of blade, which are inserted with the teeth pointed in a downward direction. In operation, the front edge of the guide block should be in line with the gullets of the teeth and should be fastened in that position. The guide post is then brought down until the hold-down foot rests lightly on the work to be sawed. For most work, the operation of the jigsaw does not differ in any important respect from that of the band saw.

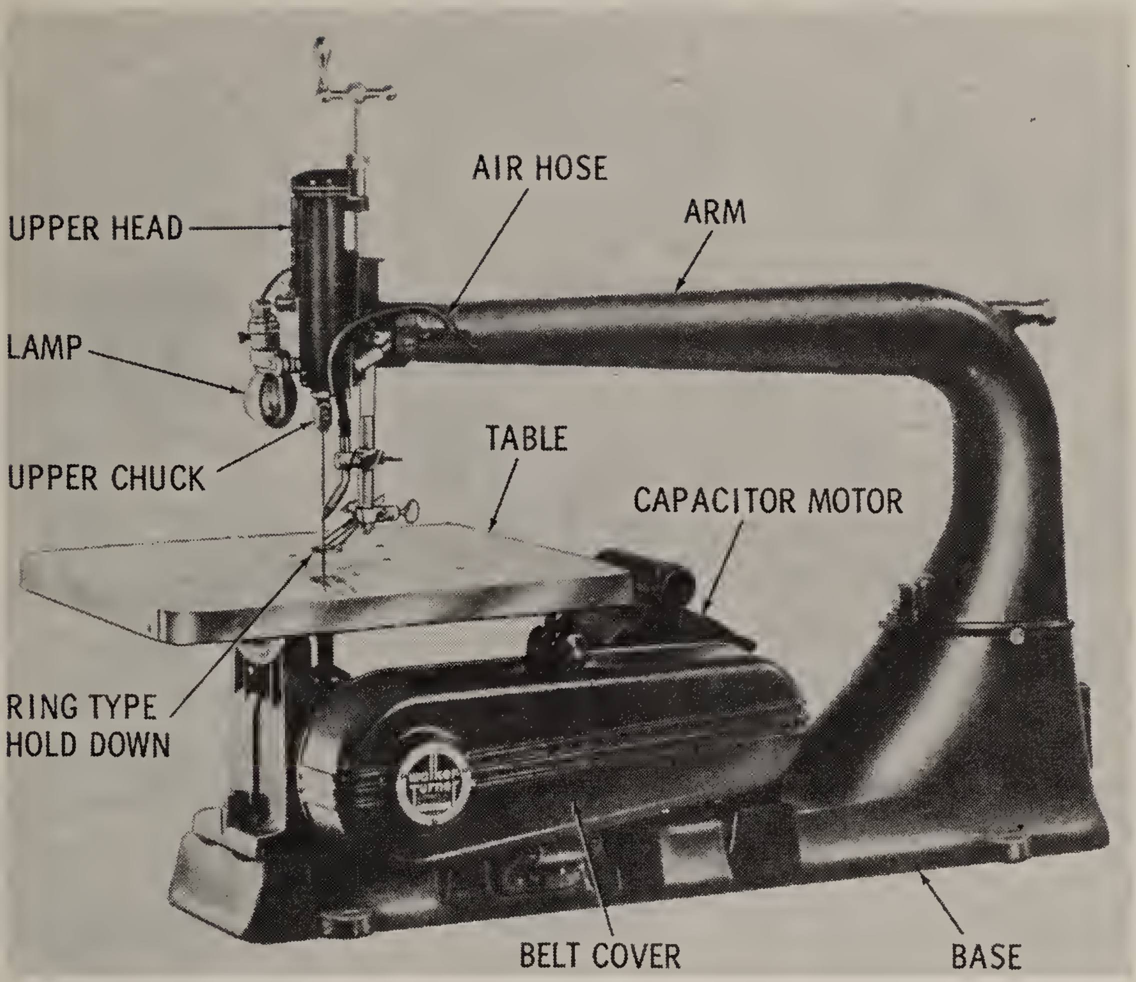


Fig. 2. Principal parts of a completely assembled jigsaw.

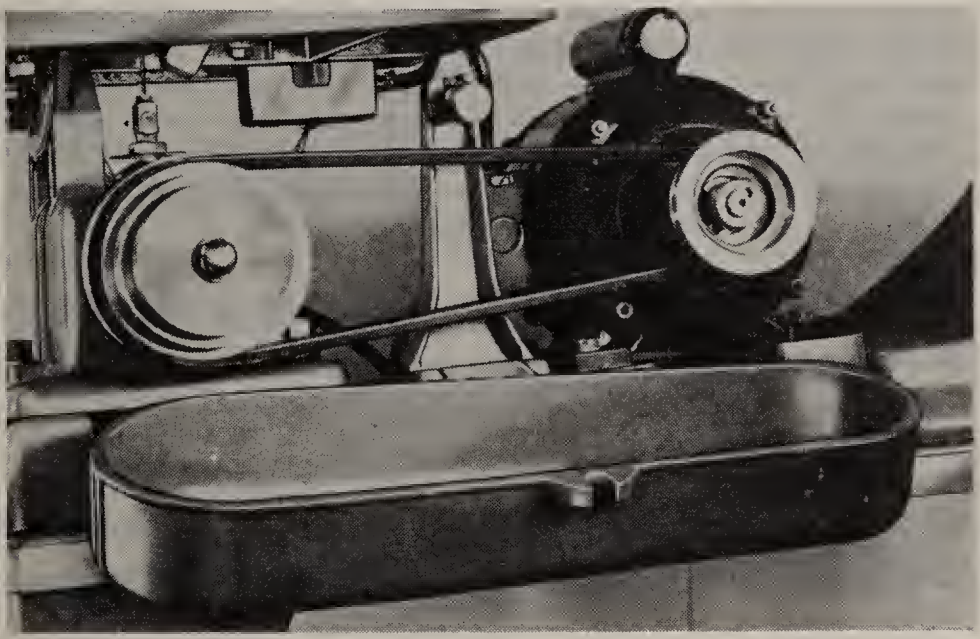


Fig. 3. Driving gears and table assembly of a typical jigsaw.

The speed of the jigsaw is generally determined by the material to be cut, as well as the type of blade used, in addition to the skill of the operator. Various speeds of from 650 to 1,700 cutting strokes per minute may be selected by the use of the proper step on the

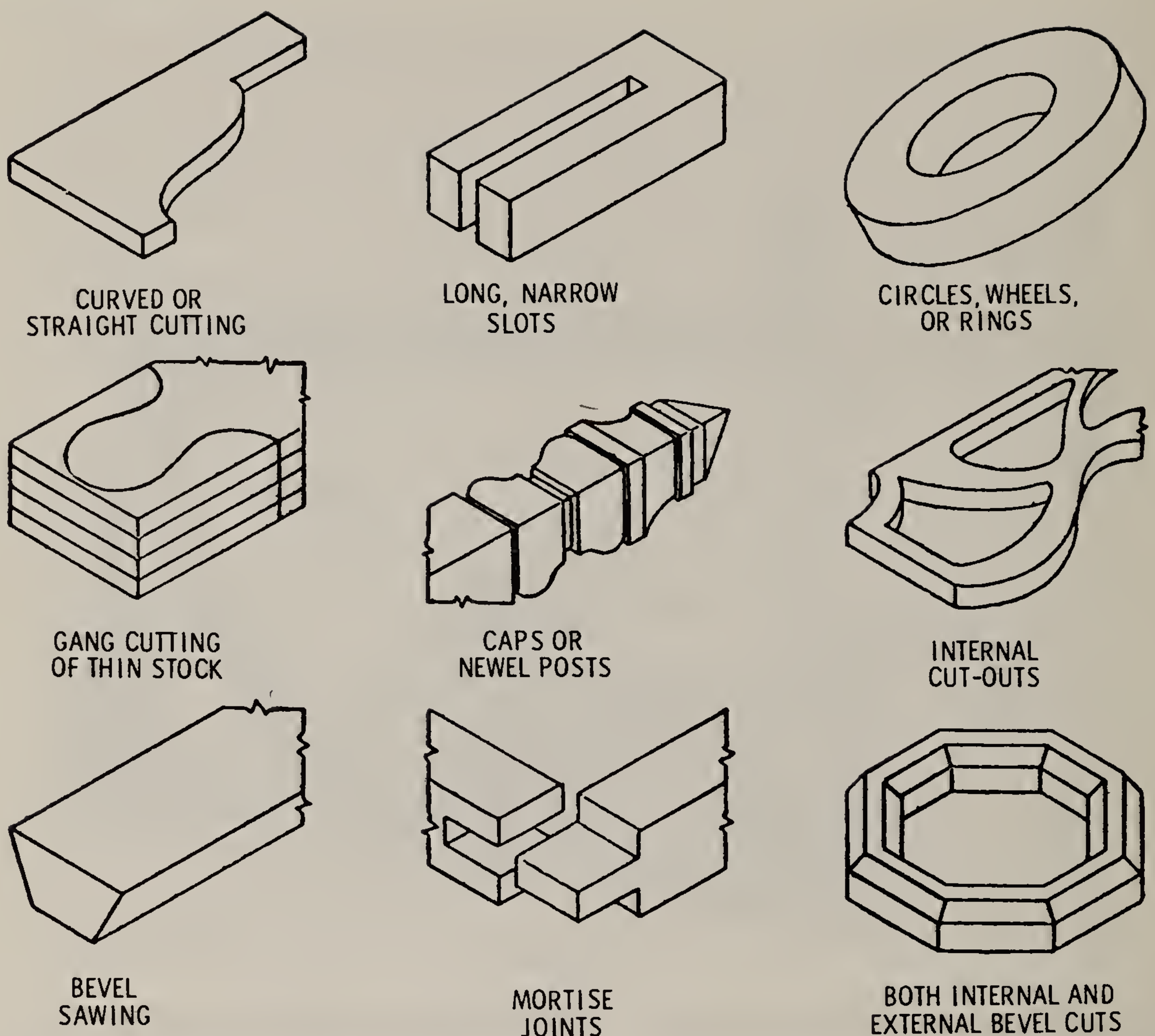


Fig. 4. Various items produced by means of jigsaw cutting. One of the most important steps in cutting any shape from wood is that of marking pattern shapes on the wood to be cut. This is usually done by drawing the pattern by the aid of suitable squares or by the use of a projector. The pattern so produced can sometimes be mounted directly on the wood as a cutting guide, or else the pattern may be produced directly on the work by means of carbon paper.

cone pulley. Jigsaw blades vary a great deal in length, thickness, width and fineness of the teeth. All blades, however, may be grouped under two general classifications, namely:

1. Blades which are gripped in both upper and lower chuck.
2. Blades which are held in the lower chuck only.

The latter types of blades are known as saber blades, whereas the former are called jeweler's blades. The jeweler's blades are useful for all fine work where short curves predominate, while saber blades are faster cutting tools for heavier materials and medium curves. When it is desirable to make inside cuts, a starting hole is drilled at a suitable location.

CHAPTER 14

The Woodturning Lathe

The woodturning lathe is a machine tool for shaping wood by causing it to revolve between centers while being acted upon by a sharp-edged cutting tool held in the hand and supported by a slide rest. Since the wood is revolving while being cut, the operation is termed *woodturning*. The principal parts of the woodturning lathe (Fig. 2) are:

1. The bed.
2. The headstock.
3. The tailstock.
4. The tool rest.

The bed is a substantial casting which resembles two parallel V-ways and is supported by cast-iron legs to bring the work to the desired height. The two V-ways carry a *headstock* at one end, and a *tailstock* at the other, the latter arranged to slide on the V-ways and to be secured at any point by tightening the tailstock clamp. The headstock is bolted to the bed and contains the driving mechanism of the lathe. This consists of a hollow spindle supported between two bearings. The spindle is revolved by a step-cone pulley and motor. Fitted into the spindle is a spur center, which engages one end of the wood to be turned, the other end being secured by the tail center.

When the spur center is caused to turn, the spurs of the spur center cause the piece of wood inserted between the centers to turn. The tool post, in common with the tailstock, can be clamped to the bed at any point desired. By resting a sharp-edged cutting tool against the T-shaped tool rest, the wood is shaved off and the surface reduced to a circular form.

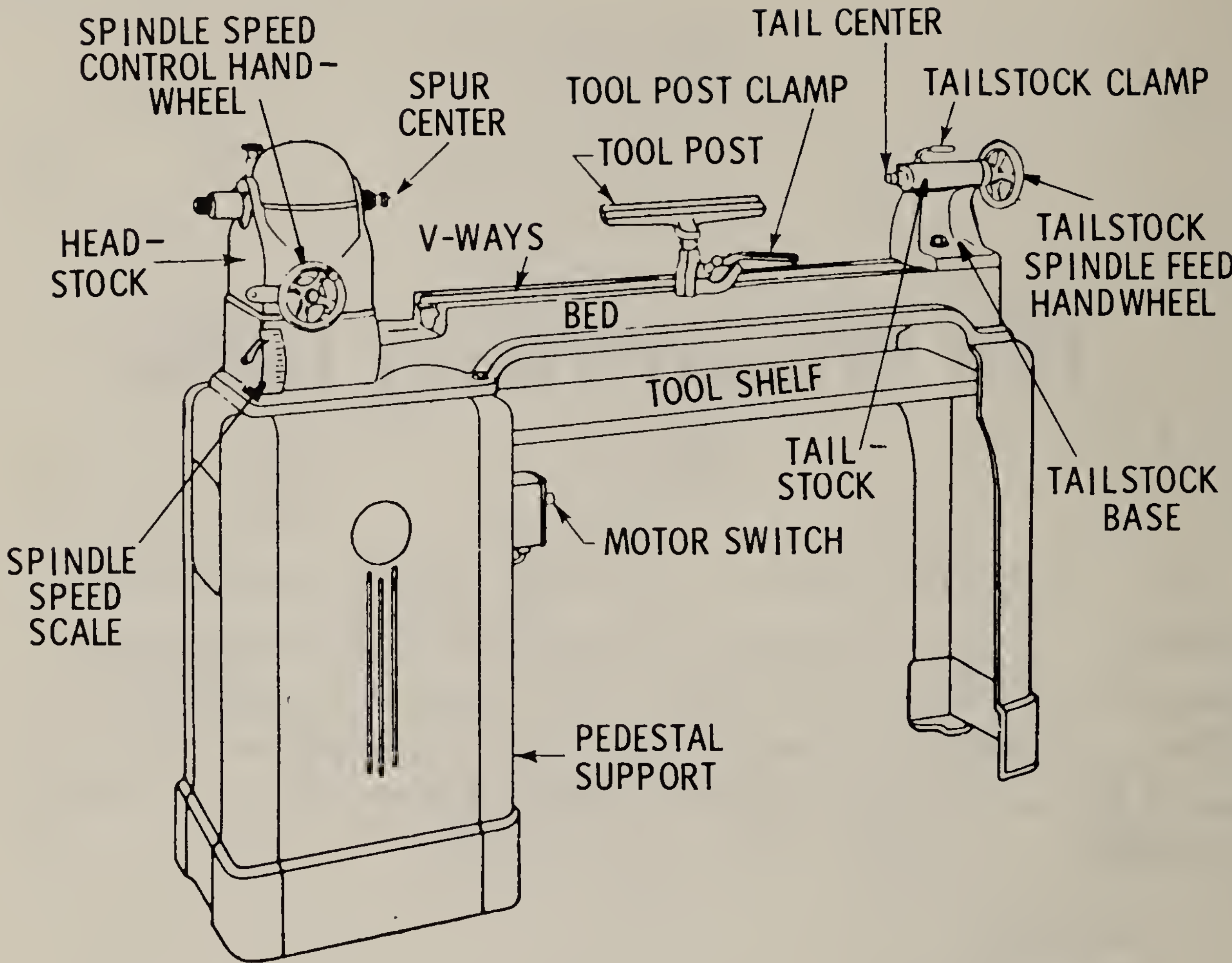


Fig. 1. Typical variable-speed woodturning lathe. While built primarily for woodturning, its heavy cast-iron headstock and double rows of preloaded spindle bearings make it an ideal machine for metal spinning as well. The spindle speed may be changed while the machine is running by means of a handwheel located in front of the headstock. Spindle speeds from 300 to 2,600 rpm may be obtained from a 1,750 rpm motor. Speed of the spindle is shown on a graduated scale located beneath the speed-changing handwheel. The variable-speed drive and motor are mounted inside the heavy cast-iron pedestal, where they are protected from dust and chips.

Lathe Speeds—The lathe speed may be regulated in several ways, depending upon the method of drive. When the lathe is driven from a set of step pulleys, the speed will range from 875 to 3,450 rpm, depending upon the type of turning to be done. No definite rule for lathe speeds can be laid down, however, due to the large variations in diameter that often occur in the work.

Starting and Stopping the Lathe—Prior to starting the lathe, the adjustments and clamps should be tested for tightness, and the work should be revolved by hand to observe that the work clears the tool post. It is better to start turning at a slower speed and increase it if necessary after the work is rough-turned and is running true. The lathe should never be run at high speed if

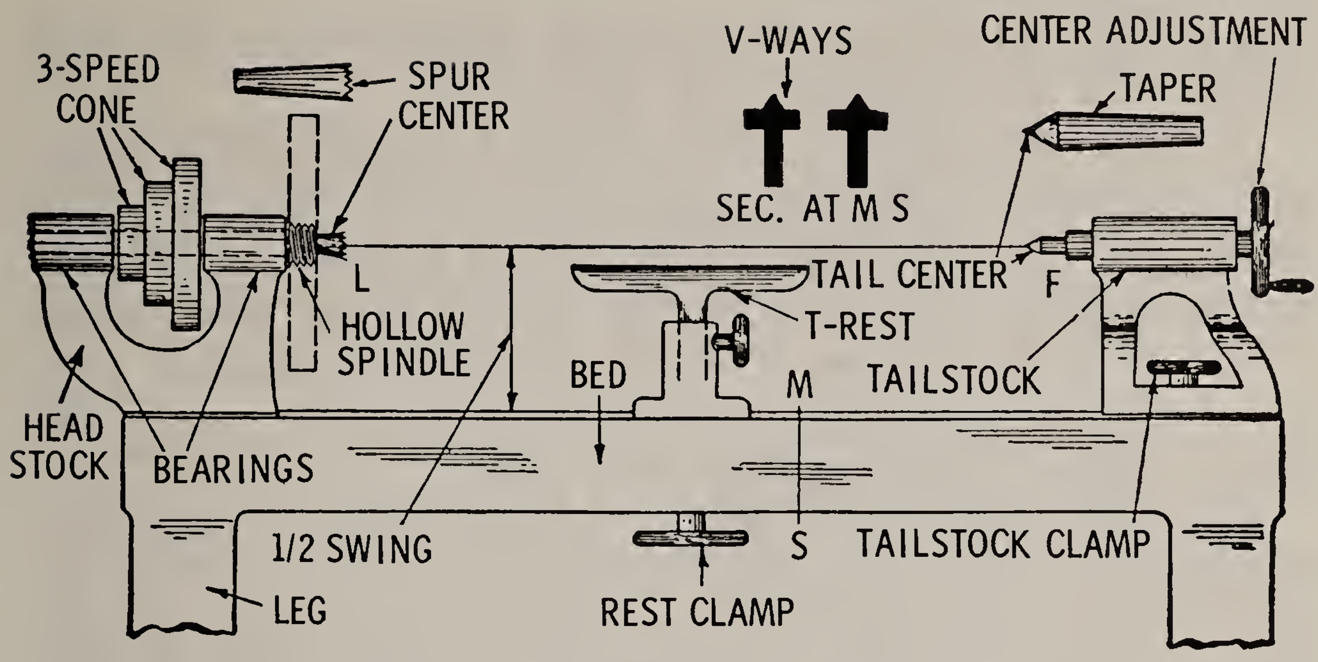


Fig. 2. Essential parts of a woodturning lathe and section of bed at MS showing V-ways which register with V-grooves cut into bottom of headstock and tailstock.

any part of the work is off center or out of balance. If the work to be turned is out of balance, it should be counterbalanced by suitable weights, although this may not always be possible. To stop the machine, the motor is turned off and braking is accomplished by placing the hand on the pulley. Large faceplate work, however, should not be stopped too suddenly in this way, as there is danger of its unscrewing from the spindle.

A smooth piece of work can be safely stopped by braking on the work itself, using a handful of shavings to prevent burning, but the lathe should never be stopped by placing the hand on the

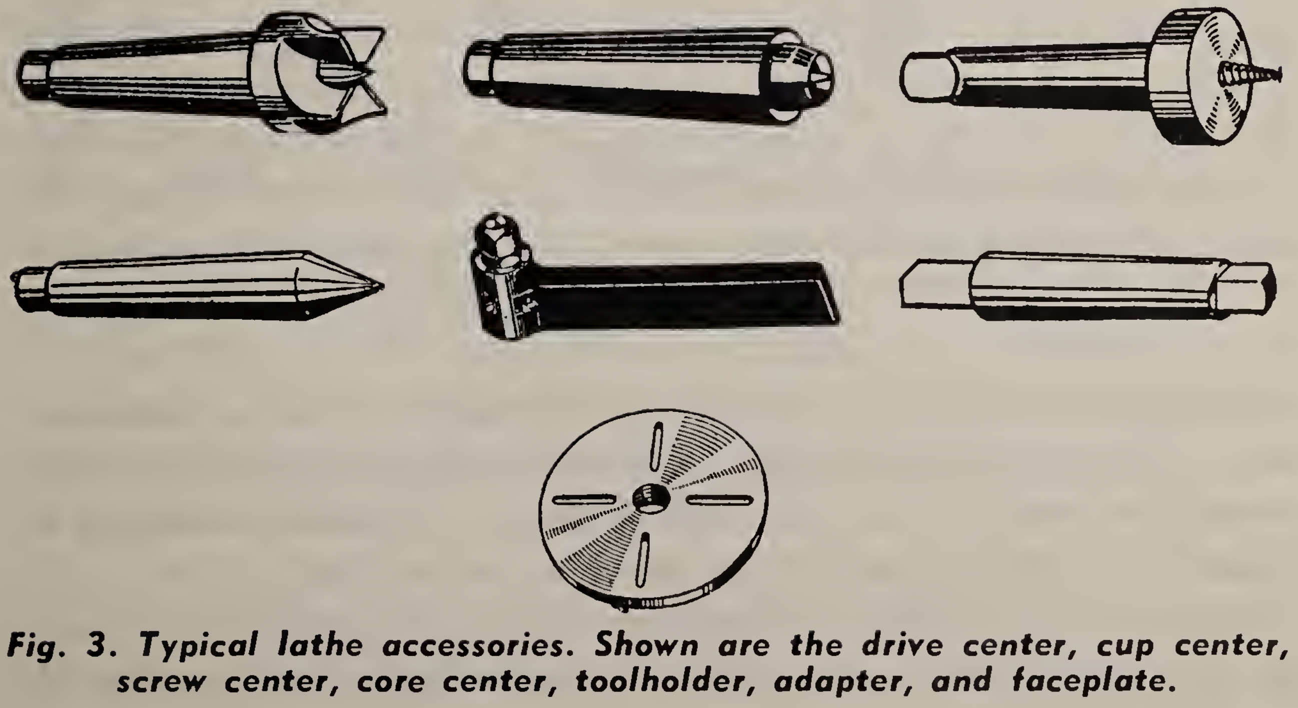


Fig. 3. Typical lathe accessories. Shown are the drive center, cup center, screw center, core center, toolholder, adapter, and faceplate.

back or edge of the faceplate, since there are likely to be projecting objects on it causing injury to the operator.

Lathe Attachments—These consist of several tools or accessories necessary to properly perform the work. They are: *lathe centers*, *drivers*, *screw chuck*, *center chuck*, *faceplate* and various turning and measurement tools. The function of the lathe centers is that of holding the work turned between the spindles. They are of three principal types; namely, the *spur* or *live center*, the *dead* or *tailstock center* and the *cup center.*

The spur or drive center (Fig. 3) is used in the live spindle for driving small and medium-sized pieces that are to be turned between centers. It is tapered to fit the hole in the spindle, and the driving end has either two or four spurs for driving purposes. The spur center is inserted in the piece to be turned by setting the point in the center of the work and driving the spurs into the work by striking the end of the work with a mallet. It is removed by pushing a ramrod through the hole in the spindle.

The tailstock center is used to support the right end of the work. It may be removed from the spindle by drawing the spindle back with the handwheel as far as it will go. The cup center (Fig. 4) is also a tailstock center and has a thin circular steel edge around

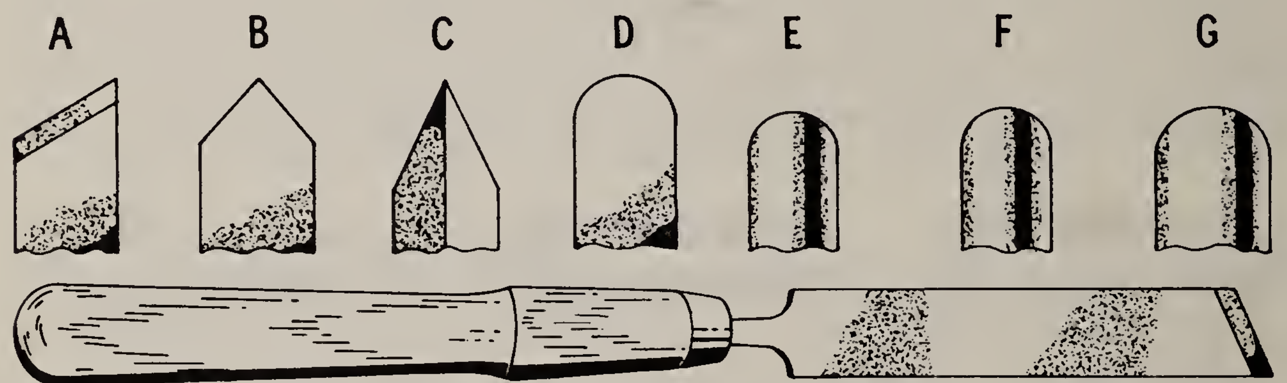


Fig. 4. Typical woodturning lathe tools. In the illustration, A represents a skew-edge chisel; B, spear-point chisel; C, parting tool; D, round-nose tool; E, F and G, gouges.

a central point. It is more accurate than the cone center and does not split the wood so easily. Since the dead center or tailstock center does not revolve, the end of the stock which turns on it should be well oiled to prevent burning by friction.

Drivers are devices other than the spur center, used for revolving the work. There are several forms used. Some are made to be

used with a small slotted faceplate and dog, as in machine-shop turning. Another form of driver is one in which the center has a square shank over which the dog fits. Screw chucks are small faceplates with a single screw hole in the center and are used for turning small pieces. There are screw chucks furnished with some lathes which hold the central screw firmly and have an attachment for regulating the projection of the screw through the face of the chuck.

Faceplates are holding devices used for work which cannot readily be driven by any of the foregoing methods. They contain screw holes countersunk on the back for the screws used in fastening the work to the faceplate. The smaller sizes are frequently provided with a recess in the center for rechucking purposes. They are made in various sizes depending upon the size of the lathe and the stock they must support. Objects such as circular disks, bowls, trays, etc., are always turned on faceplates.

Woodturning tools are used for cutting and scraping purposes. The most common are various types of gouges, chisels and parting tools. Gouges are beveled on the outside or convex side, and the length of the bevel is about twice the thickness of the steel. Skew chisels are beveled on both sides, and the cutting edge forms a 60° angle with one side of the chisel. Parting or cutoff tools are thicker in the center of the blade than at the edges and thus will not bind or overheat when a cut is made. This tool is used for making narrow cuts to a given depth or diameter.

Other necessary tools are those used for measurements, usually termed *sizing* and *layout tools*. The tools for sizing and layout work in the lathe should include both *inside* and *outside calipers*, as well as *dividers* and *trammels*. The latter should be of a type fitted with both outside and inside caliper points as well as the ordinary trammel points. Measuring rods are also used for sizing both the inside and outside of a ring-formed object.

How to Take Accurate Measurements—The ability to take accurate measurements plays an important part in woodturning work and can be acquired only by practice and experience. All measurements should be made with an accurately graduated scale. Never use a cheap steel scale or a yardstick, as they are likely to be inaccurate and may cause ruined work. An experienced operator can take measurements with a steel scale and calipers to

a surprising degree of accuracy. This is accomplished by developing a sensitive caliper feel and by carefully setting the calipers so that they split the line graduated on the scale.

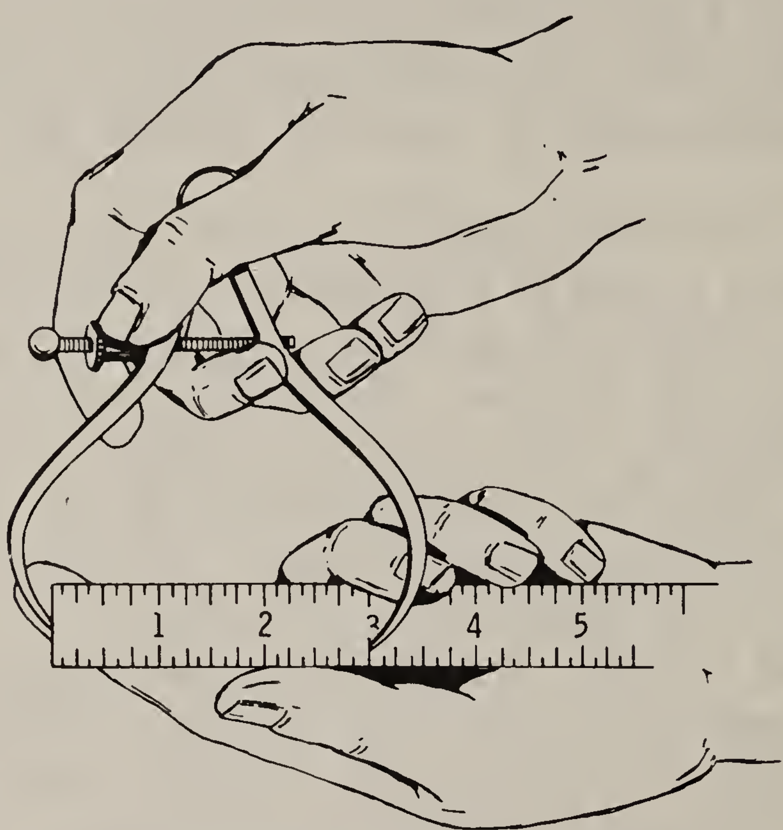


Fig. 5. Setting an outside caliper.

A good method for setting an outside caliper to a steel scale is shown in Fig. 5. The scale is held in the left hand and the caliper in the right hand. One leg of the caliper is held against the end of the scale and is supported by the finger of the left hand while the adjustment is made with the thumb and first finger of the right hand.

The proper application of the outside caliper when measuring the diameter of a cylinder or a shaft is shown in Fig. 6. The caliper is held exactly at right angles to the center line of the work and is pushed gently back and forth across the diameter of the cylinder to be measured. When the caliper is adjusted properly, it should easily slip over the shaft of its own weight. Never force a caliper or it will spring and the measurement will not be accurate.

To set an inside caliper for a definite dimension, place the end of the scale against a flat surface and the end of the caliper at the edge and end of the scale. Hold the scale square with the flat surface. Adjust the other end of the caliper to the required dimen-

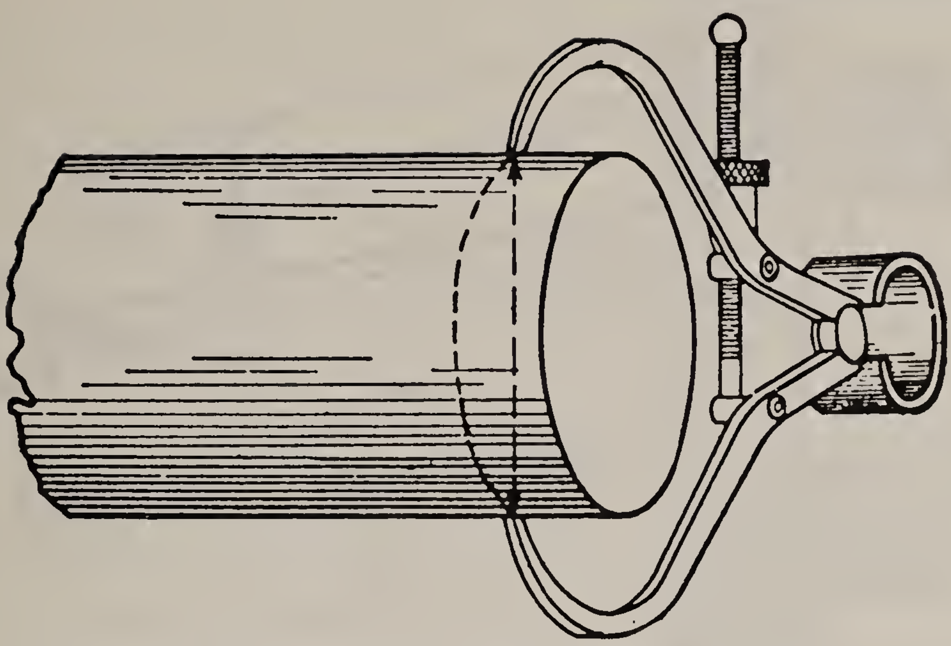


Fig. 6. Measuring with an outside caliper.

sion as shown in Fig. 7. To measure an inside diameter, place the caliper in the hole as shown on the dotted line and raise the hand slowly, as illustrated in Fig. 8. Adjust the caliper until it will slip into the hole with a very slight drag. Be sure to hold the caliper square across the diameter of the hole.

In transferring a measurement from an outside caliper to an inside caliper, the point of one leg of the inside caliper rests on a similar point of the outside caliper, as shown in Fig. 9. Using this contact point as a pivot, move the inside caliper along the

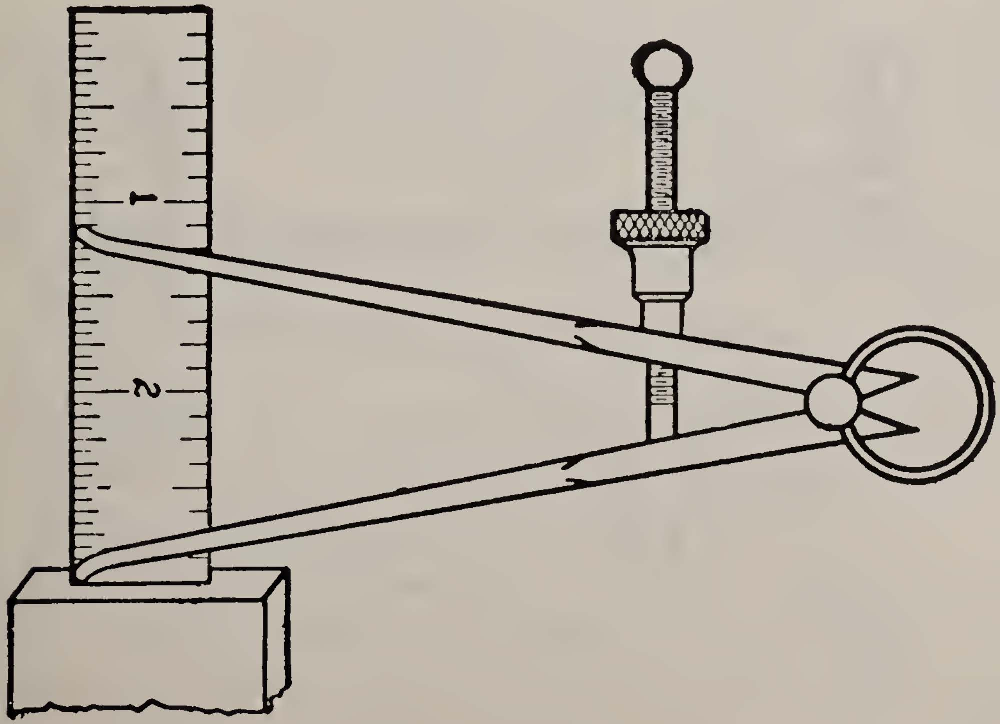


Fig. 7. Setting an inside caliper.

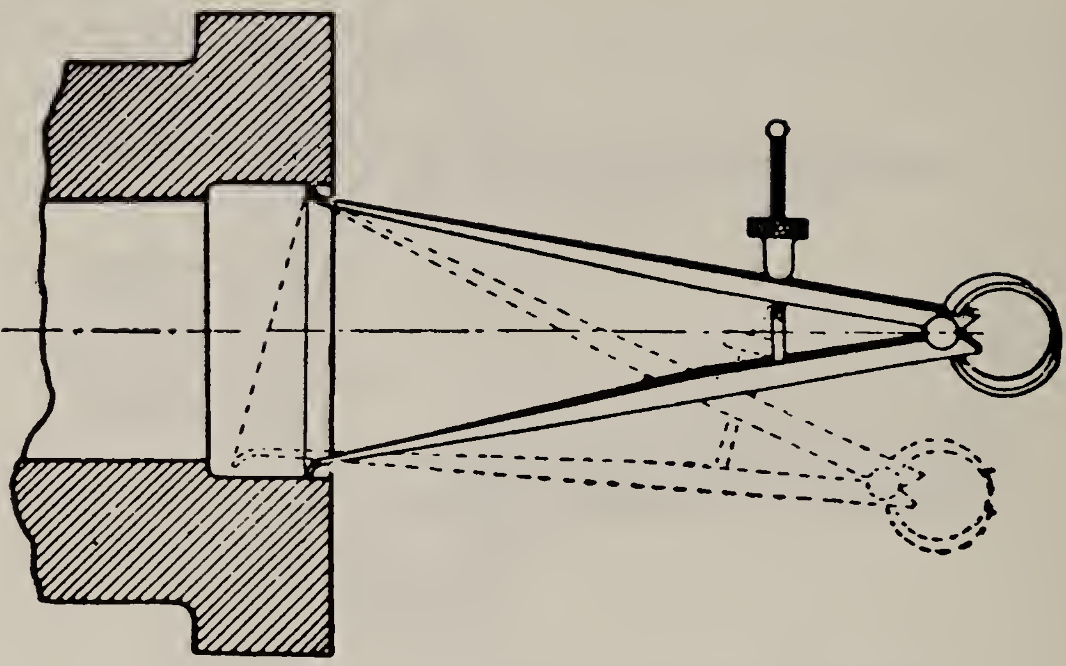


Fig. 8. Measuring with an inside caliper.

dotted line shown in the illustration and adjust with the thumb-screw until the measurement is just right.

The hermaphrodite caliper shown in Fig. 10 is set from the end of the scale exactly the same as the outside caliper. The accuracy of all contact measurements is dependent upon the sense of touch or feel. The caliper should be delicately and lightly held in the finger tips, not gripped tightly. If the caliper is gripped tightly, the sense of touch is very much impaired.

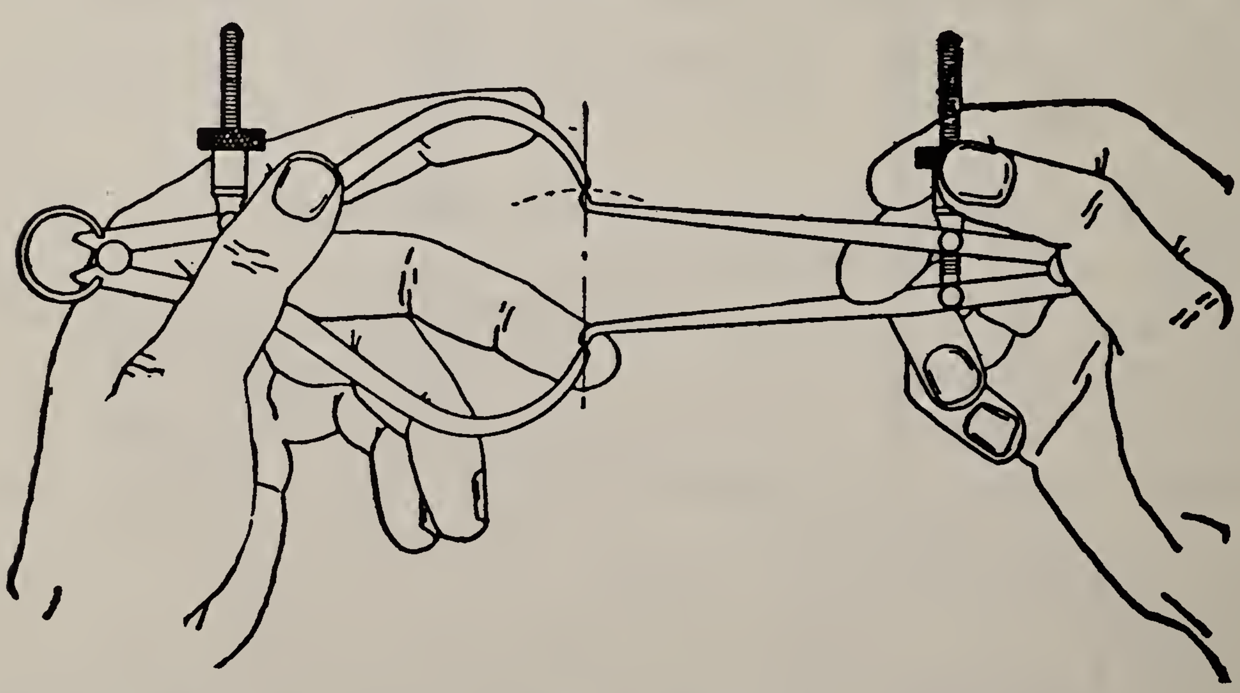


Fig. 9. Method of transfer of measurement from an inside to an outside caliper.

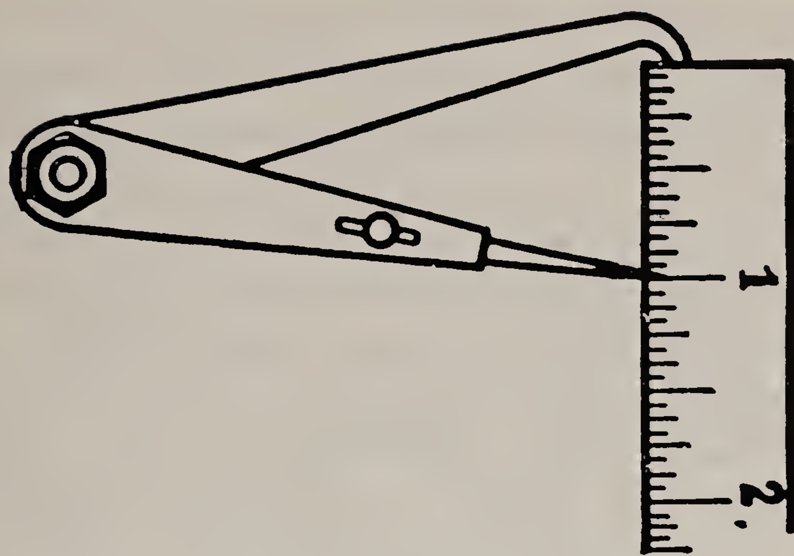


Fig. 10. Setting of hermaphrodite caliper.

Centering and Mounting Stock—Wood stock to be turned must be properly marked; that is, the true centers must be obtained prior to turning. On square stock, the center is most commonly obtained by the diagonal method, which consists of drawing lines from corner to corner, the intersection of the lines marking the center of the work. Round stock is most frequently centered

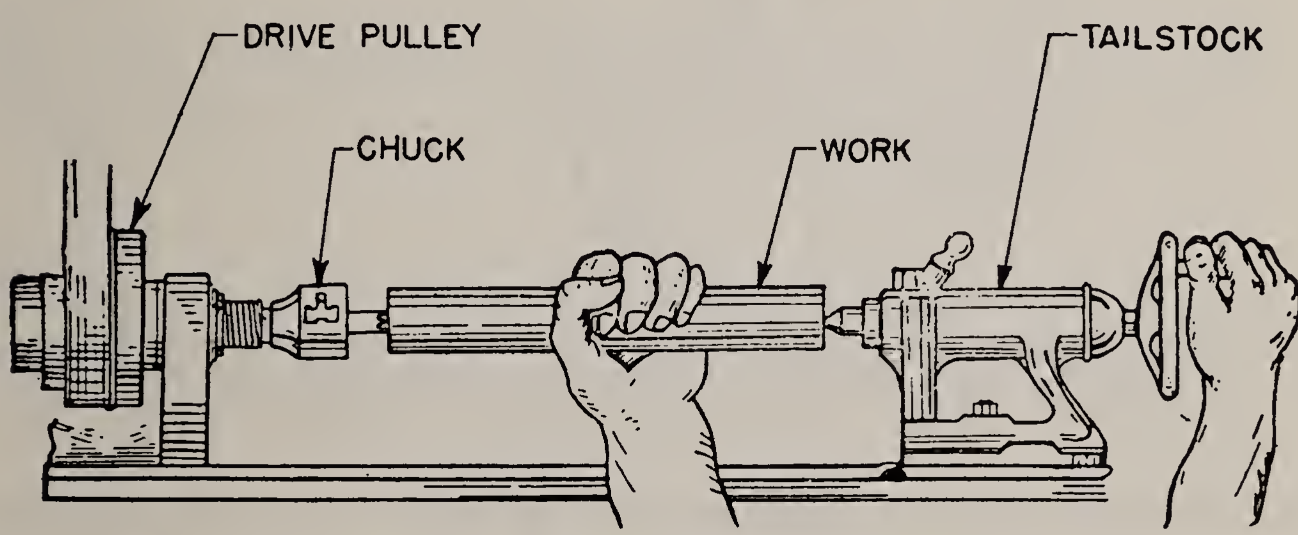


Fig. 11. Mounting work in lathe.

by the combination square method, which consists of holding the center head of a combination square firmly against the work and drawing two lines across each end of the work.

After the work center has been marked, the work can be mounted in the lathe. The stock is first pressed against the spur or live center so that the spurs enter the stock. Next move the tailstock up to about an inch from the end of the stock and lock it in this position. Then advance the tailstock center by turning

the feed handle until the center makes contact with the work. Continue to advance the center while slowly rotating the stock by hand. After it becomes difficult to turn the stock, slack off on the feed handle about one-quarter turn and lock the quill spindle. The stock is now ready for turning. The tool rest is next mounted in position so that it is level with the centers and about ⅛ inch away from the stock. Clamp the tool rest in position and revolve the stock by hand to make certain it has sufficient clearance.

Typical Woodturning Operations—The most common woodturning operations concern such simple steps as roughing

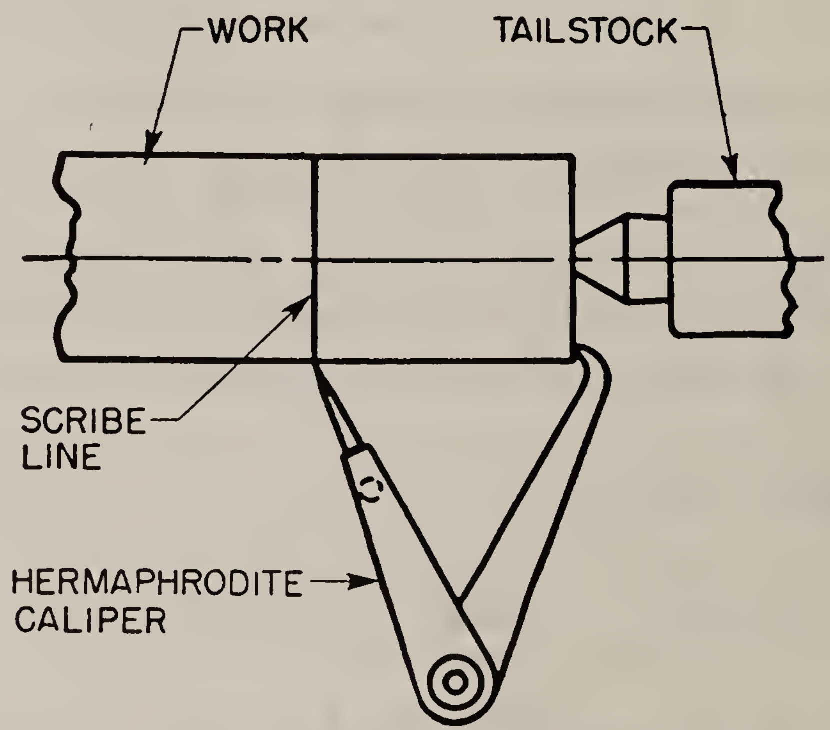


Fig. 12. Marking length of work. Set the hermaphrodite caliper to the required dimension and scribe a line around the revolving work with the sharp point of the caliper.

off, paring or finishing, squaring of ends, making concave or ring cuts, etc. In a roughing-off cut, place the large gouge on the tool rest so that the level is above the center of the wood and the cutting edge is tangent to the "circle of cut." In adjusting the tool rest, the handle should be well down. Roll the gouge over slightly to the right so that it will shear instead of scrape the wood. Lift the handle slowly, thus forcing the cutting edge into the wood. First remove the corners in this way, then the intervening portions. The tool should be held at a slight angle to the axis of the wood being turned, with the cutting end in advance of the handle as shown in Fig. 14.

In paring or finishing cuts, lay the skew chisel on the tool rest with the cutting edge above the cylinder and at an angle of about 60° to the surface. Slowly draw chisel back, raising the handle until

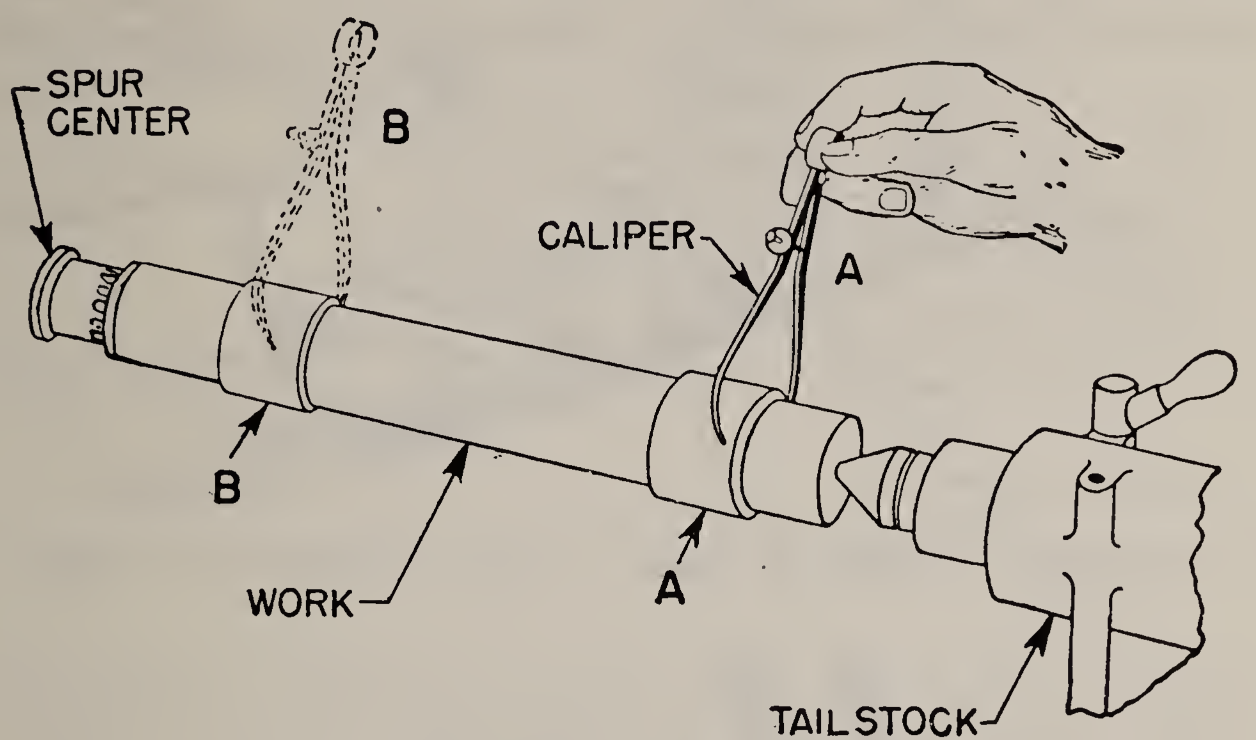


Fig. 13. Taking measurements on work while in the process of being turned. Here collar A is measured and, without making any adjustment on the caliper, collar B is tested to see how it compares with collar A. If collar B is not the same diameter as collar A, then the adjustment of lathe centers is not correct, and the tailstock should be adjusted in the direction required.

the chisel cuts about ¼ to ⅜ inch from the heel. Begin the first cut from one to two inches from either end pushing toward the near end. Then begin at the first starting point and cut toward the other end, thus taking off the rings left by the gouge, cutting down to where the scraped sections are just visible. Now take a last cut, removing all traces of the rings, bringing the wood down to a uniform diameter from end to end.

After the work has been reduced to a cylinder, the ends may be set up or squared to mark the end of the turning. This work is commonly accomplished by placing the ¼- or ½-inch skew chisel on the tool rest, bringing the cutting edge next to the stock and perpendicular to the axis. The heel of the chisel is then slightly tipped from the cylinder to give clearance. Raise the handle and push the chisel toe into the stock about ⅛ inch outside the line indicating the end of the cylinder. Swing the handle still further from the cylinder and cut a half V, giving clearance and preventing

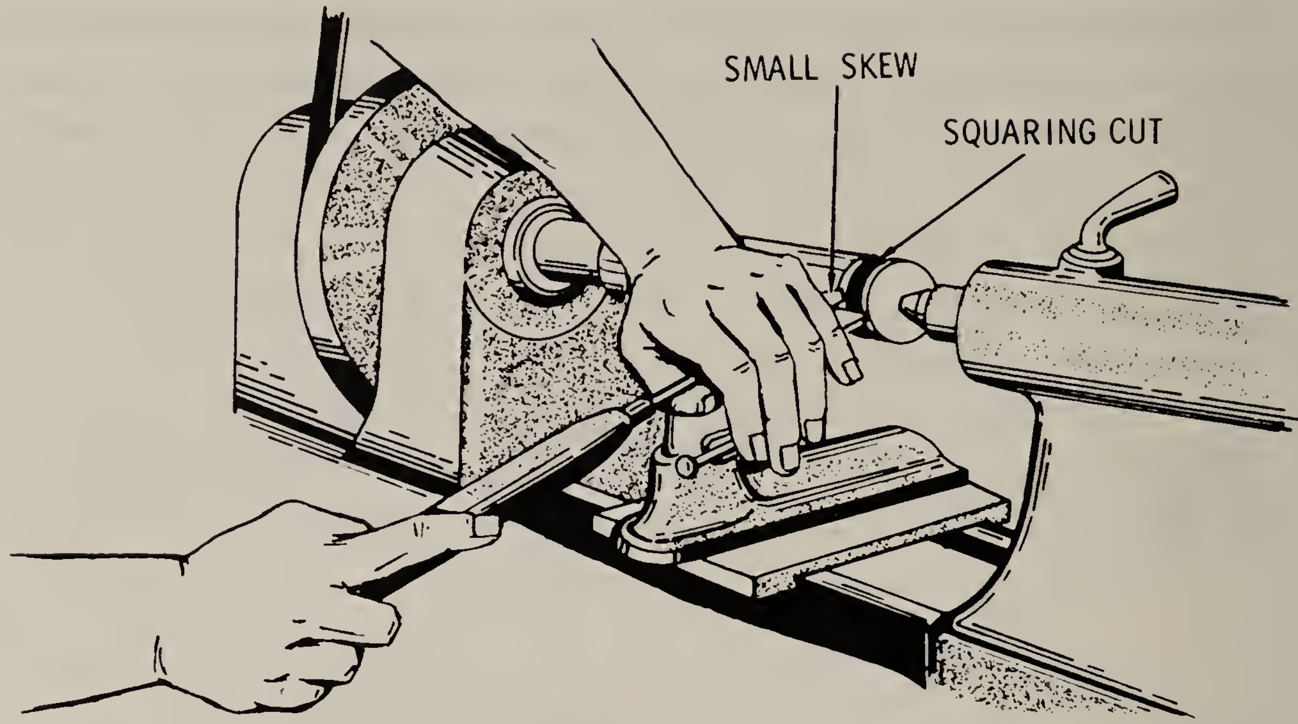


Fig. 14. Method of holding the gouge in making roughing cuts on lathe.

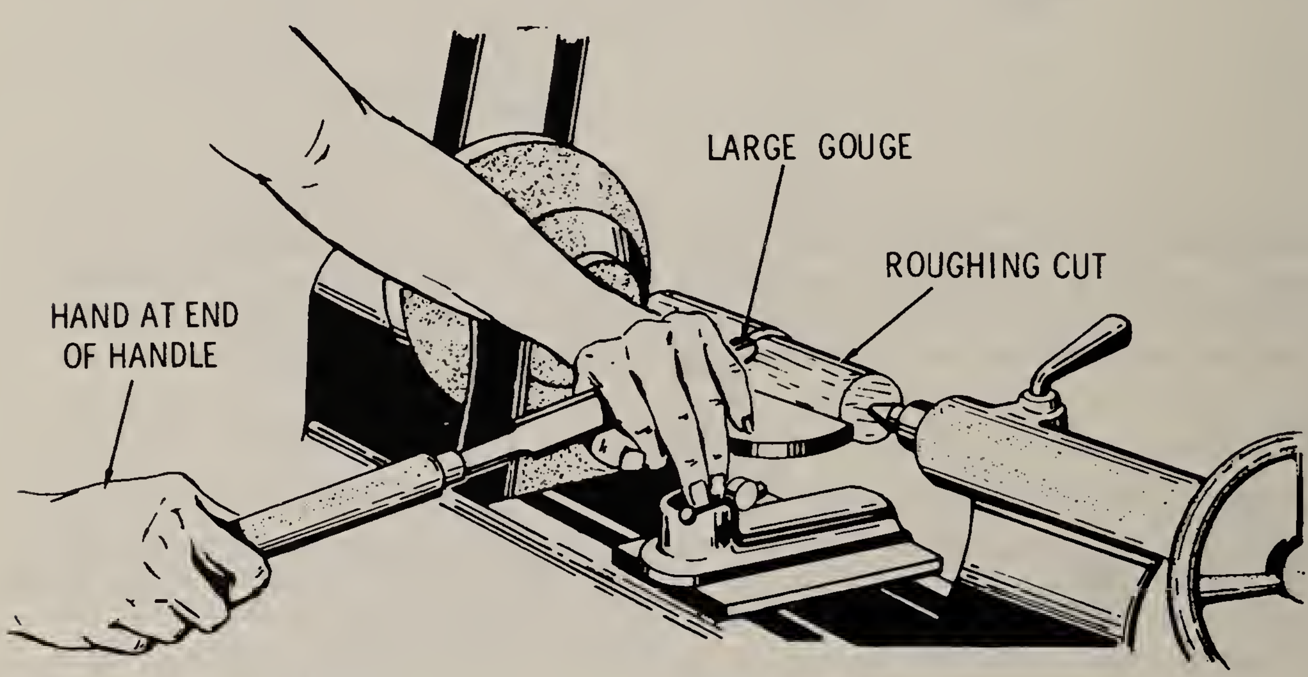


Fig. 15. Holding tool when squaring the ends of work.

burning (continue until the cylinder is cut to about 1/16 inch in diameter).

TYPES OF CUTS IN WOODTURNING

In addition to cylindrical turning and taper work, there are three other common types of cuts in woodworking. These are:

1. V-cuts.
2. Convex cuts, or beads.
3. Concave or cove cuts.

Sharp vees are cut best with a small skew chisel. Fig. 16 shows the proper method for starting the cut. After the work has been marked, start the first groove with the heel of the tool. Then push down on the tool rest and raise the chisel handle, forcing the heel of the skew into the work. As the groove becomes deeper, be careful to keep the unengaged portion of the cutting edge from digging in. After cutting the groove, turn the chisel blade to the position shown in Fig. 17, and cut the sides of the vee, first one side and then the other, until reaching the proper depth. *Never* feed in the tool fast enough to burn the tool edge. Be particularly careful when turning hardwoods.

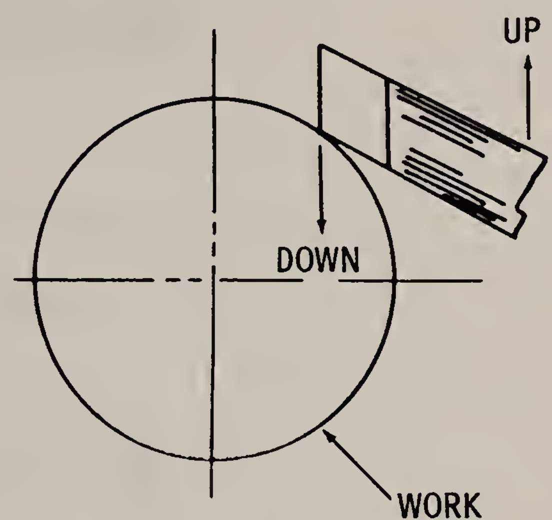


Fig. 16. Method of holding tool when starting a vee-cut near the headstock.

Convex cuts or *beads* are also best made with a skew chisel. Various stages of the cutting process are illustrated in Figs. 18 to 22. The first grooving is made exactly the same as for a V-cut and at the point which will be the end of the bead, as noted in Fig. 18. Then start the cut from the center of the bead as shown

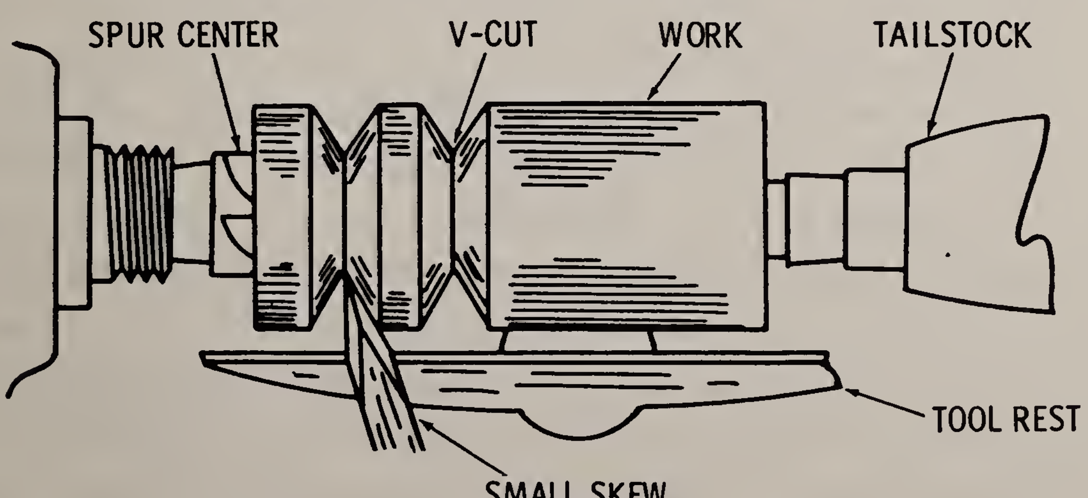


Fig. 17. Position of tool in groove when cutting.

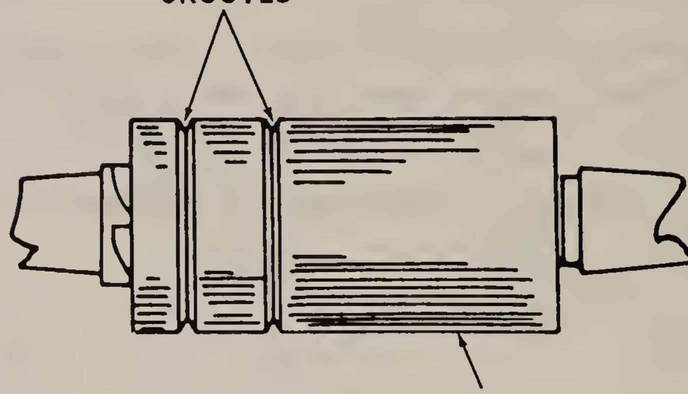


Fig. 18. First grooves for convex cut.

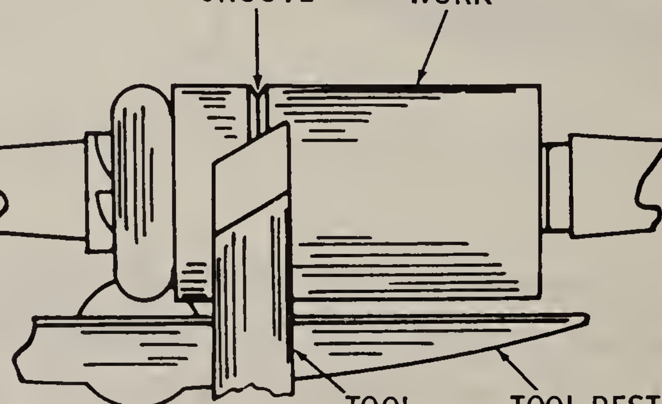


Fig. 19. Position of tool when starting to shape the cut.

in Fig. 19. Hold the blade fairly flat and high enough on the work so that only the heel will cut. Work the tool toward the side (Fig. 20) and at the same time draw it forward to avoid cutting the adjacent stock. As the groove becomes deeper, keep the back edge of the blade from spoiling the slope of the bead and remember to draw forward as the work progresses.

Concave cuts are usually made with the small gouge although a round-nose scraping tool may also be used. In making concave cuts with the small gouge, first make sizing grooves with the parting tool as shown in Fig. 24. Then cut a groove to approximate shape by pushing the tool directly into the work with a scraping cut as shown in Fig. 25. Then start the tool with the ground portion at a right angle to the side of the groove (Fig. 26) and roll the tool down to the groove center as shown in Fig. 27, cutting with the side lip of the tool. Then reverse the blade and repeat for the other side of the groove. *Never attempt to take a cut from the bottom to the top of the groove.*

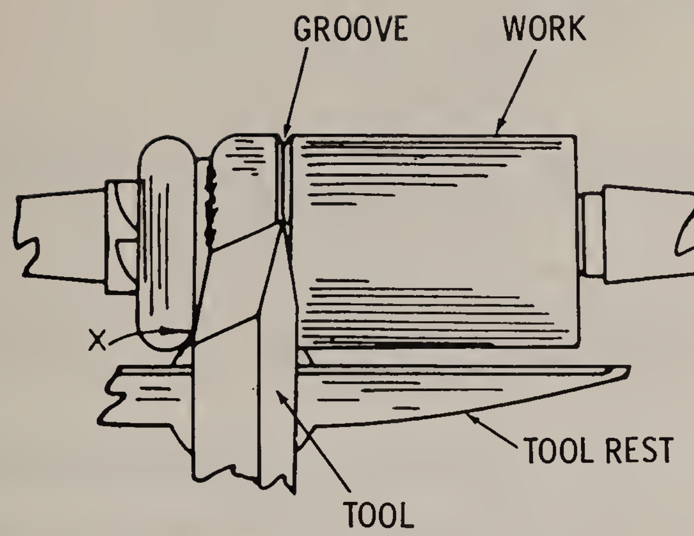


Fig. 20. Tool will rub at "X" if not drawn forward as work progresses.

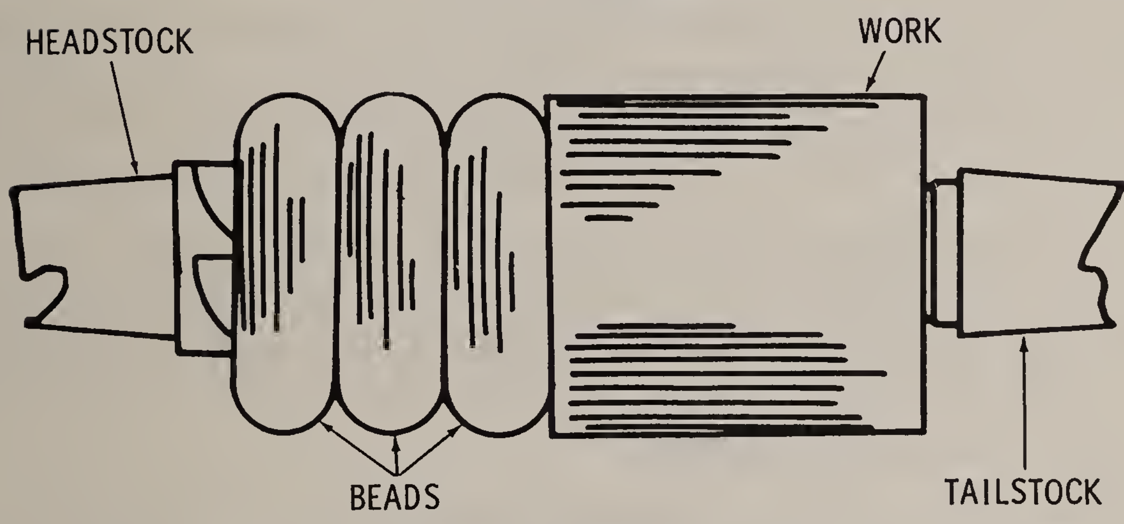


Fig. 21. Completion of typical beads or convex cuts.

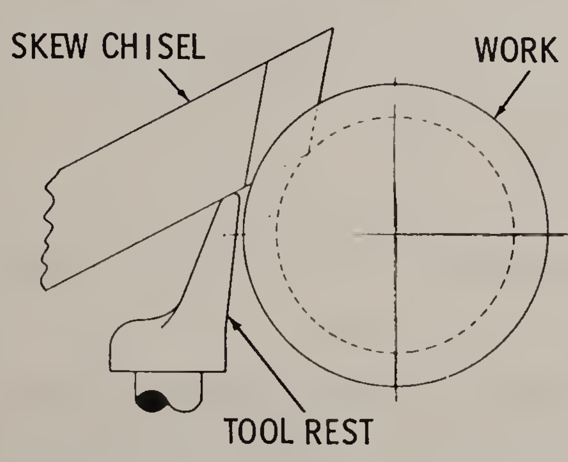


Fig. 22. Position of chisel when finishing bead cut.

When using the round-nose scraping tool to make a concave curve, the chisel is pushed into the work with a scraping cut. The handle is then shifted so that the groove is gradually widened and deepened until finished.

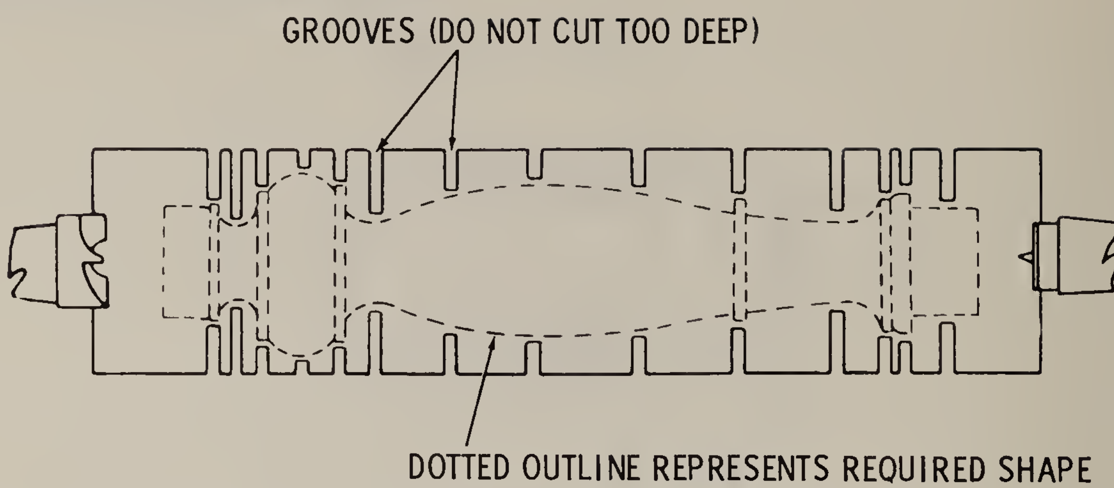


Fig. 23. Parting tool used to cut grooves at various points of the work to be turned to a required shape. Each groove is cut nearly as deep as the finish diameter, allowing about 1/8 inch for finishing.

Cutting Square Corners—When cutting square corners, the small skew chisel is held as shown in Fig. 28. Here the surface of the ground portion is held parallel to the shoulder and when the tool is swung farther toward the shoulder, the cutting action is likely to be stopped. Similarly, when the tool is swung too far away from the shoulder, the chisel point digs in. Cutting up to a shoulder on a cylinder requires considerable practice. Hold the point of the small skew chisel as shown in Fig. 29, so that the heel of the tool takes a light cut.

Cutting Off—Although the parting tool can be used for a rough cutting-off job, a smooth, accurate end surface requires both the parting tool and the small skew chisel. In marking the work for cutoff, allow at least two inches at the headstock end and enough at the tailstock end to clear the cup center point by half an inch or more. Figs. 30, 31, and 32 give detailed cutting-off instructions.

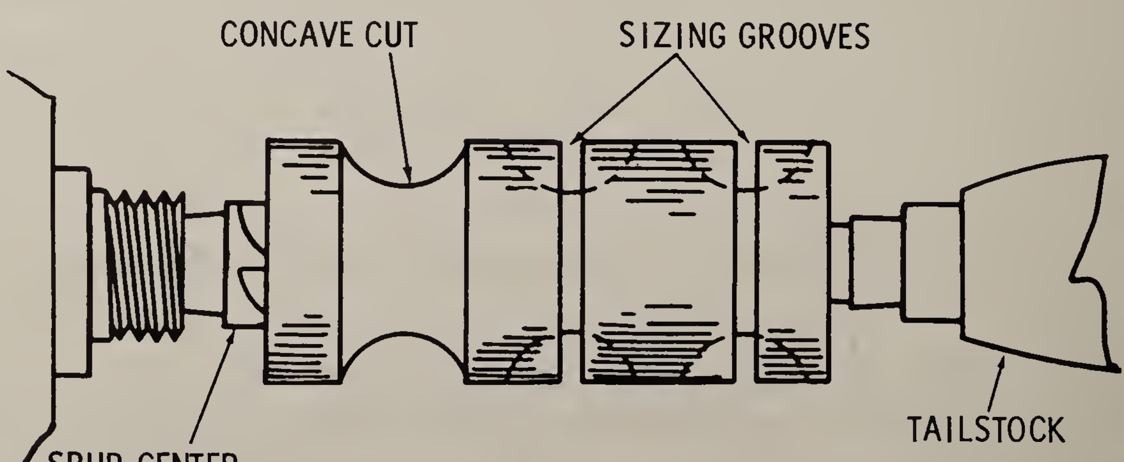


Fig. 24. Starting a concave or cove cut. Note sizing grooves cut in the work prior to commencing the cove cuts.

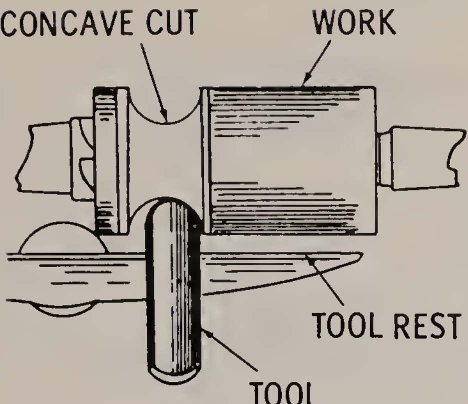


Fig. 25. Method of roughing out the curve. The tool is pushed directly into the work with a scraping cut.

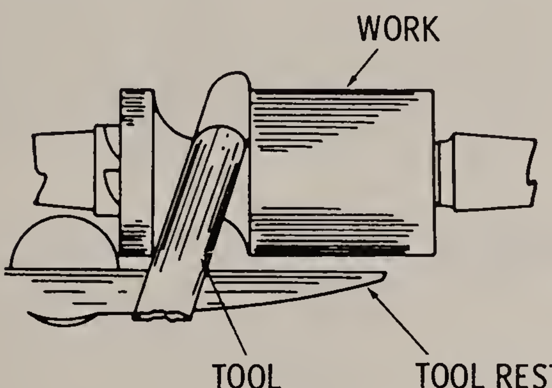


Fig. 26. Proper tool position at start of "rolling" cut. The ground portion of the tool is at right angles to the side of the groove.

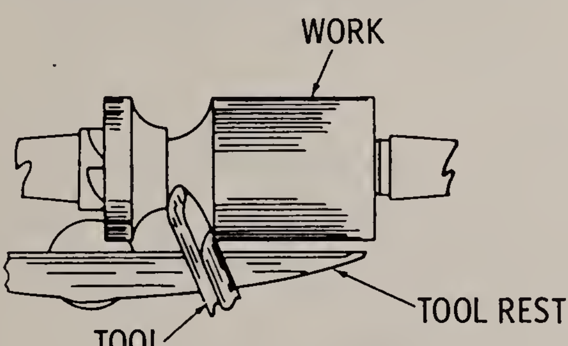


Fig. 27. Tool position at the end of the "rolling" cut. The cutting has been done with the side tip of the chisel.

Faceplate Turning—Work which cannot be turned between centers is fastened to a faceplate or held in a chuck. The screw center is considered a special type of faceplate for small work. Fig. 33 shows a typical faceplate operation. There are several methods of fastening the work to the faceplate. Figs. 34 and 35 serve to illustrate three types of fastening methods. Short heavy screws are inserted in the holes of the faceplate and are turned directly into the stock if the screw holes will not be objectionable in the finished work.

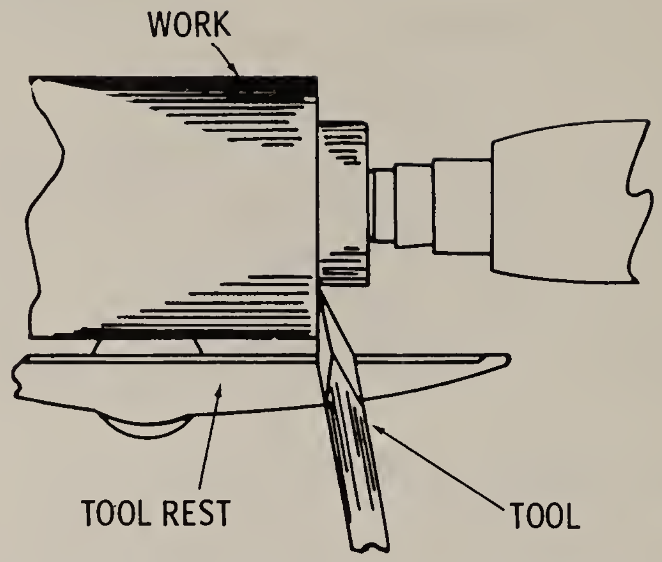


Fig. 28. Using the small skew chisel to cut a square corner. The ground portion at the left is held parallel to the shoulder.

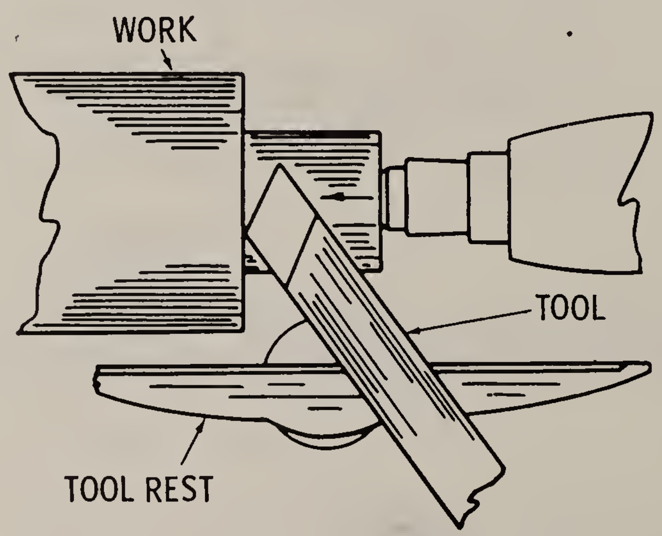


Fig. 29. Cutting up to a shoulder with the small skew chisel. The arrow indicates proper direction for advancing tool.

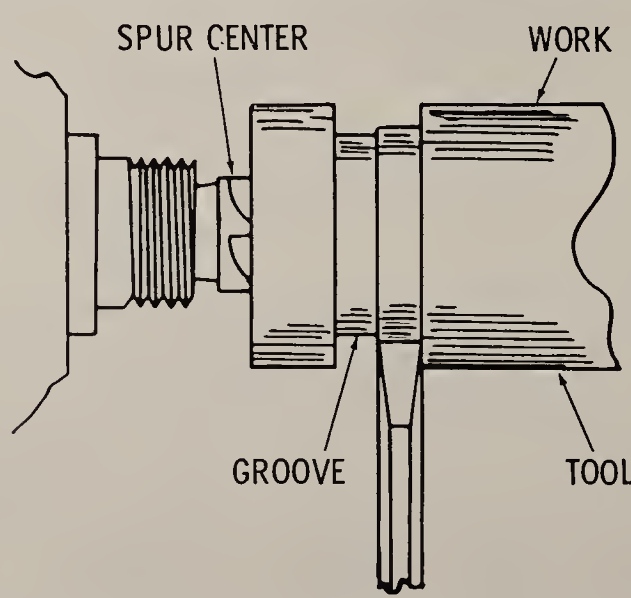


Fig. 30. First step in a clean cutoff job. Use the parting tool to cut a groove about 3/8 inch wide and deep enough to leave a diameter of about 3/4 inch at each end of the work. As shown at the left, this groove is made by taking two separate cuts with the parting tool.

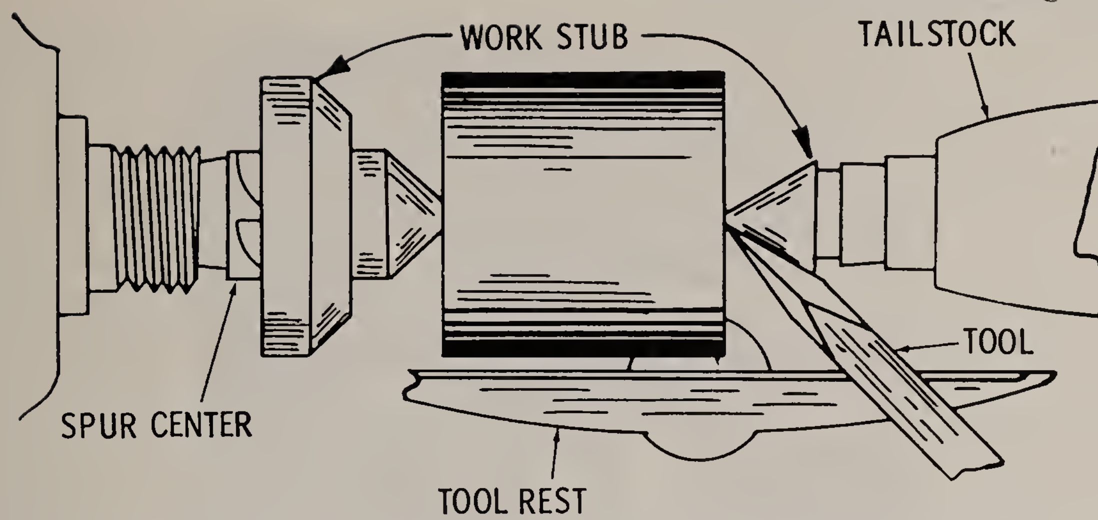


Fig. 31. Cut a wide groove at each end with small skew chisel, holding tool as for cutting shoulders. Pare off end to correct dimension, keeping groove well cut out and clear. Continue cut until diameter is about 3/32 inch at tailstock and 1/8 inch at headstock. Be sure ends are smooth and clean.

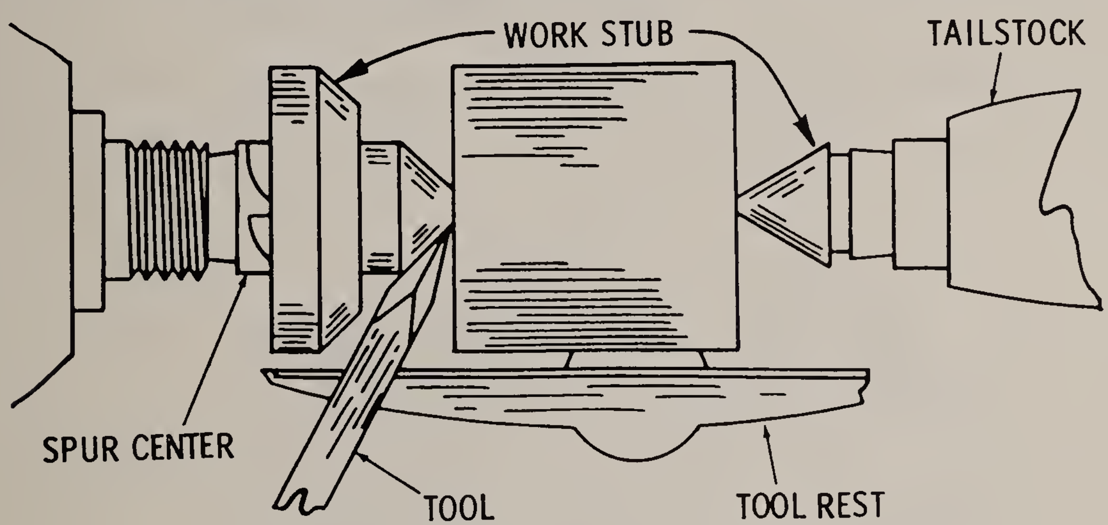


Fig. 32. The final part of the cutting-off procedure consists of cutting off the headstock end with the chisel point, catching the work with the left hand as it falls. Cut off the small tailstock end with the skew or with a sharp knife. Some operators prefer to stop the lathe when the groove diameters are about 1/4 inch and finish the cutoff with a saw.

When screw holes must be avoided, the work is glued to a piece of scrap stock, and the screws tightened into the scrap stock as shown in Fig. 34. A piece of newspaper placed between the two pieces simplifies removal of the work from the scrap after the operation is completed. When mounting small work on the screw center (Fig. 35), first drill a hole for the screw. Apply soap to the screw when mounting hardwoods to facilitate the disassembly after the work is finished.

Another method of fastening stock to the faceplate is to screw a scrap piece to the plate and turn this until it runs true and flat.

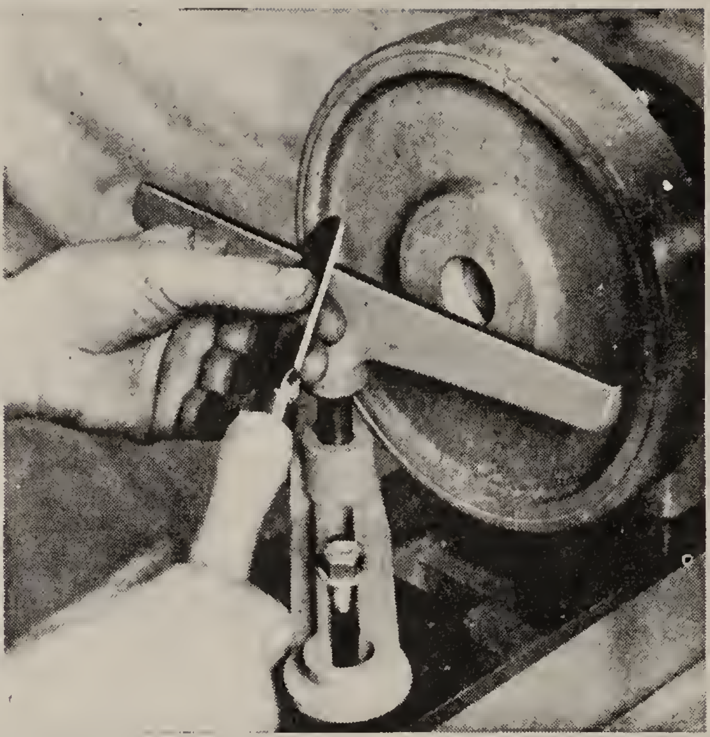


Fig. 33. Position of tool when making a facing cut.

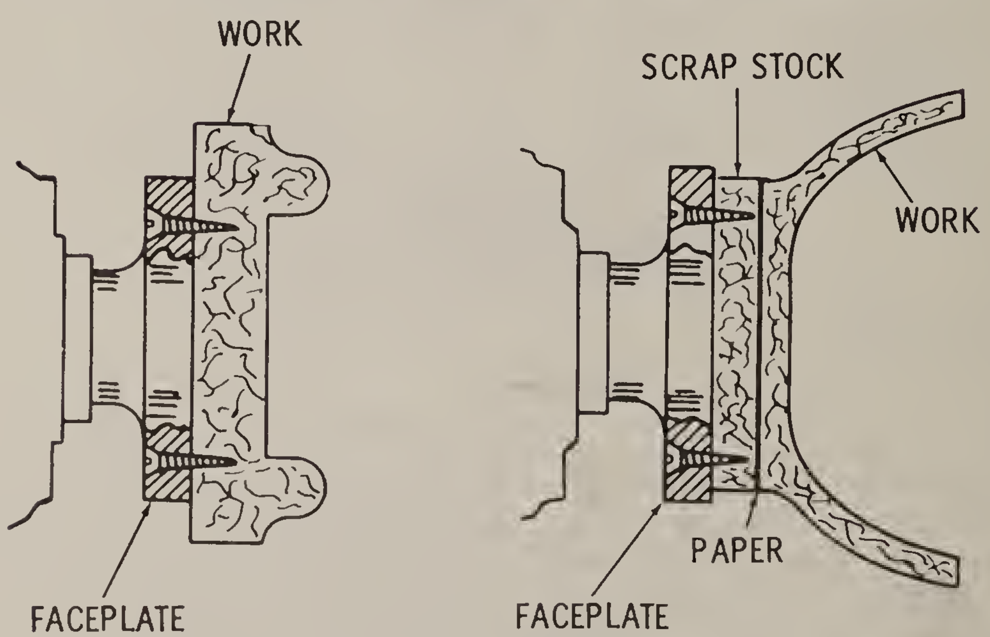


Fig. 34. Two methods of mounting work for faceplate turning. (A) The screws are turned directly into the work, (B) Stock may be glued to a piece of scrap for holding purposes.

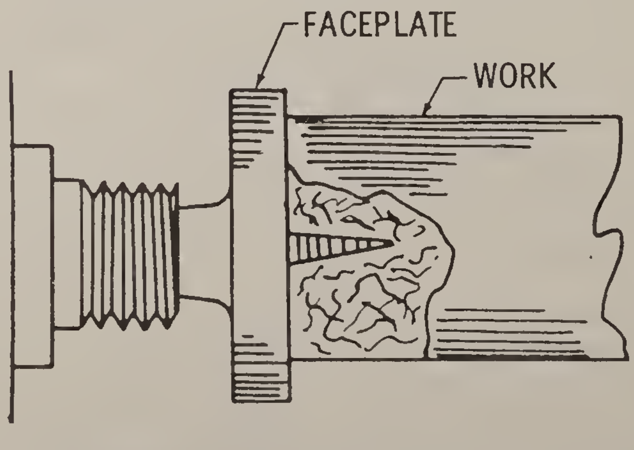


Fig. 35. Work mounted on screw center for faceplate operation.

The stock to be turned may then be glued directly to this first piece, or a piece of heavy paper may be glued between the two pieces of wood. This method of fastening stock is used for faceplate turning when the material for turning is not thick enough to take screws.

Scraping Method of Faceplate Turning—A scraping cut is accomplished with the scraping chisel held horizontally and flat into the work as illustrated in Figs. 36 and 37. Because faceplate turning requires cutting the grain of the wood in all directions, the paring or cutting method used on work between centers is not satisfactory. The large gouge, however, may be used for roughing cuts in the same manner as when turning work between centers.

Ordinary parting tools are not used for scraping cuts because the larger clearance of the bevel of the parting tool causes the cutting edge to dull quickly. Sometimes the small skew is used for taking convex scraping cuts. Before turning down irregular-shaped

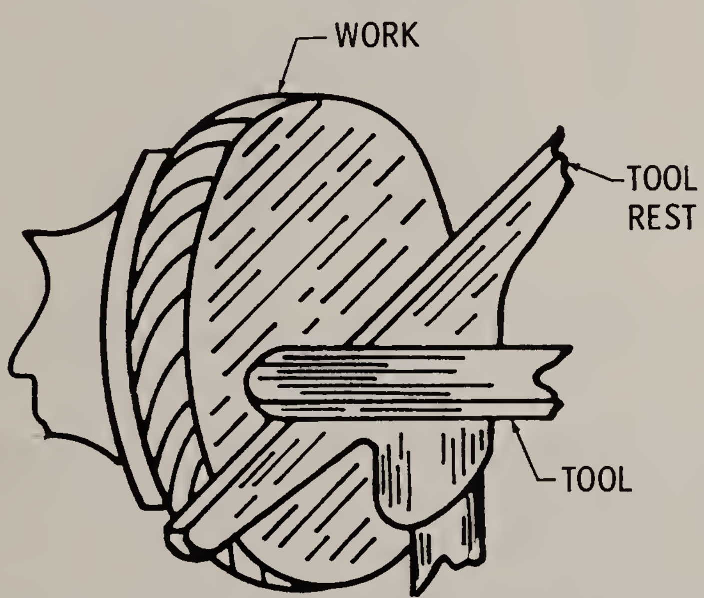


Fig. 36. Tool position for scraping cut when facing.

work on the faceplate, saw off the corners or cut them down to approximate shape with a jigsaw. Take light cuts to avoid splitting off corners or tearing the work from the faceplate. Figs. 37, 38, and 39 show the use of scraping tools in three typical facing operations.

Woodturning Chisels—Fig. 40 shows some of the common woodturning chisels, the principal types being the spear-point scraping chisel, the gouge chisel, skew chisel and parting tool. The spear-point chisel is used for cutting and scraping purposes

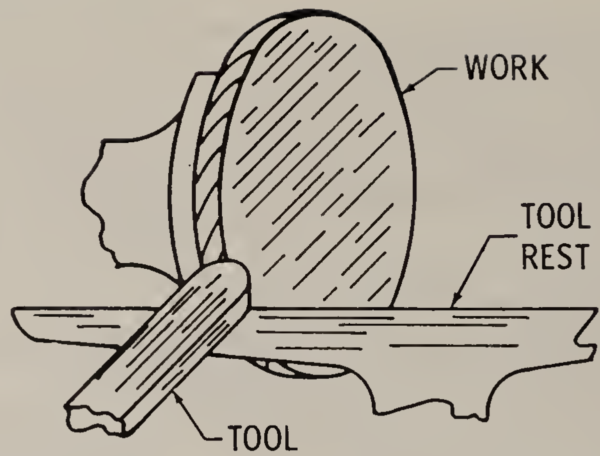


Fig. 37. Position of tool using a square-end scraper on the outer edge of faceplate work.

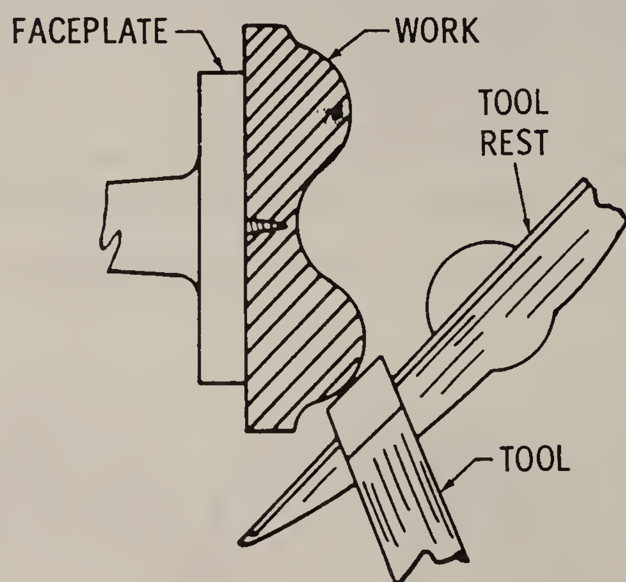


Fig. 38. Position of tool when taking a convex scraping cut with the small skew chisel.

and is beveled on both of its flat sides. The gouge chisel is used to rough down the stock so that it will be approximately its largest diameter when completed, for concave cuts, etc.

The skew chisel is used for smooth-cutting on cylindrical or long taper work. The cutting edge is askew or at an angle, and both side faces are ground to permit cuts to the right or left. The parting tool is used primarily for taking sizing cuts which serve as a guide in turning to size and also for cutting-off operations. The parting tool is a double wedge, wider at the center to provide clearance. The point is ground so that the cutting edge is on the exact center of the tool.

Sanding and Finishing—Having completed the actual turning on the lathe, the sanding operation should be done. A speed one step faster than that used for general turning is usually fast enough for most sanding work (see woodturning speed table). The

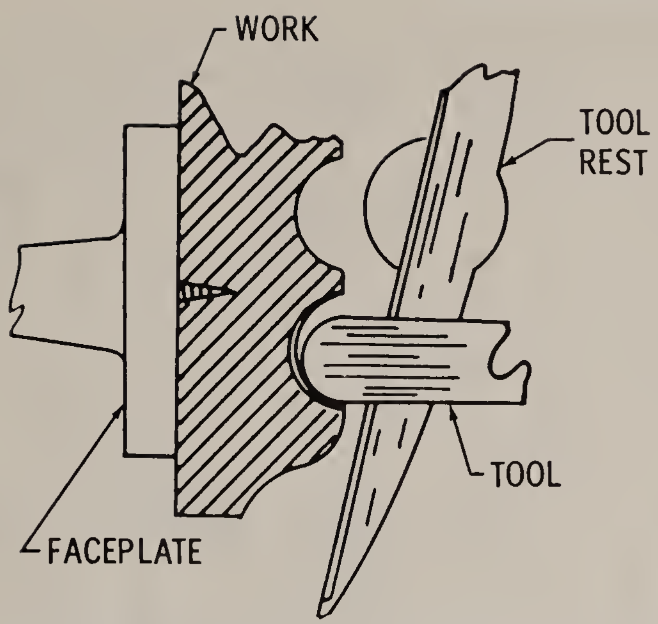


Fig. 39. Method of taking a concave scraping cut with the round-nose scraper.

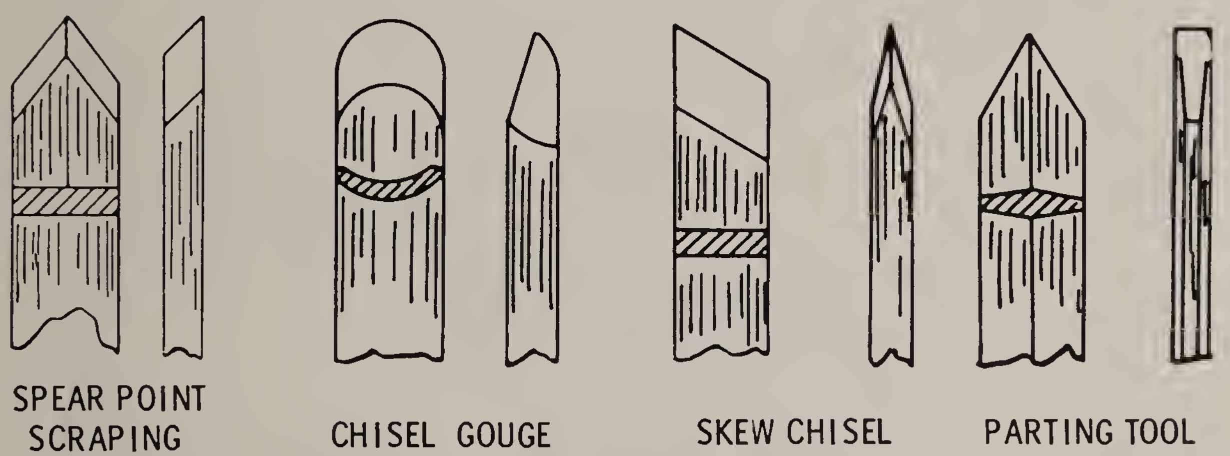


Fig. 40. Common woodturning chisels.

lathe speed should never be so fast as to burn the wood or paper.

The important point in sanding is to remember that the sandpaper should not be held stationary at one point, but it should be moved slowly back and forth along the piece to prevent rings and scratches. In sanding taper cuts, follow the same procedure as when sanding a cylinder, and if a sharp angle is desired, care should be taken that the sandpaper is not run over the vertex of the angle, as this will round the edge and eliminate the sharp corner. Here again, the sandpaper must be moved back and forth along the cut and not held stationary.

Never wrap the sandpaper around the work and grasp it with the fingers. Tear the sandpaper in strips and hold the ends only, or hold an end in one hand and the other against the bottom of the work with the fingers of the other hand. Hold the paper lightly against the work without pressure. Always remove the entire tool

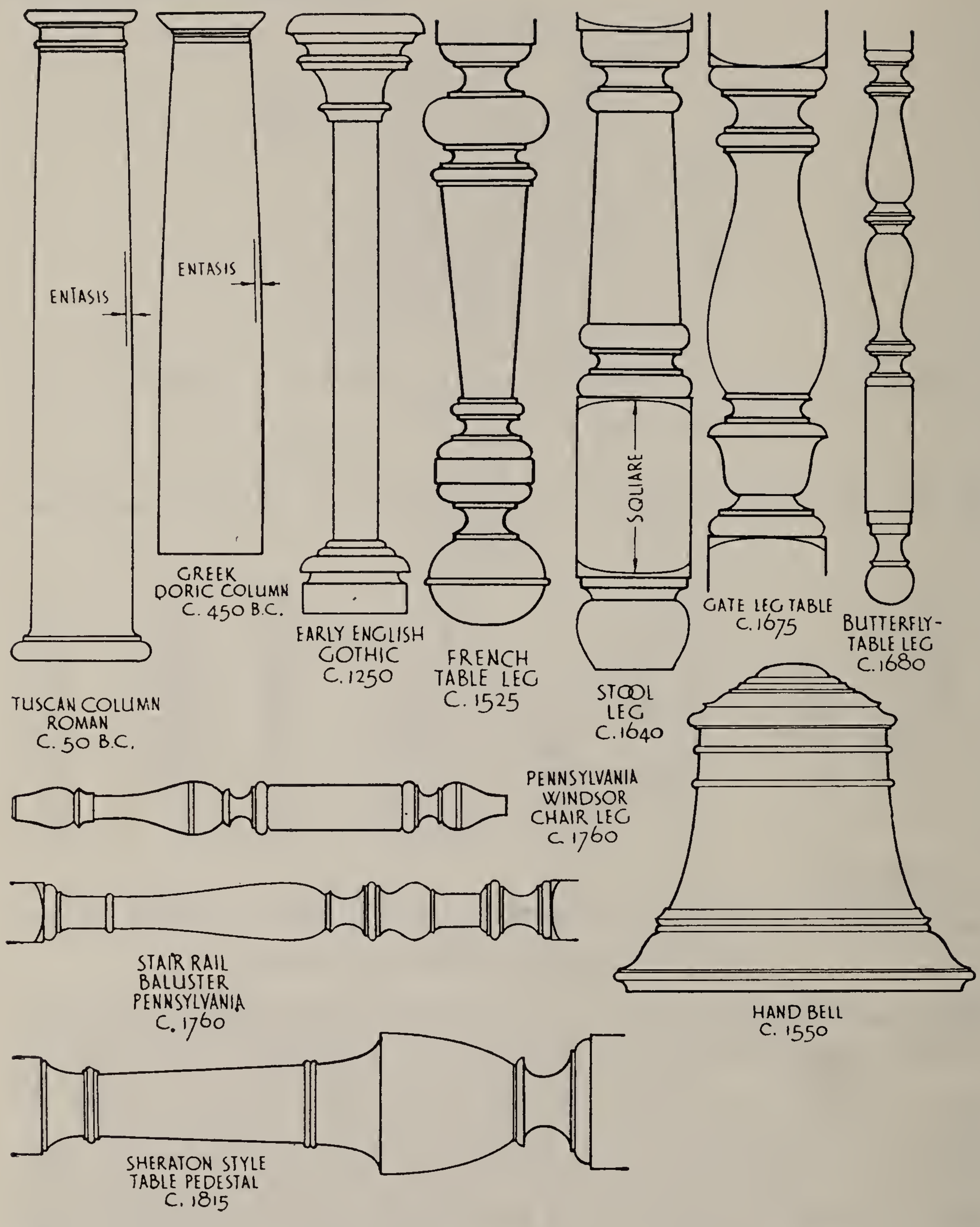


Fig. 41. Examples of antique woodturning collected from remote periods of antiquity up to the early nineteenth century.

rest before sanding a piece of work. If the work has been turned properly, only a moderate amount of sanding with No. 4/0 paper will be necessary. A short preliminary sanding with No. 1/0 paper is required only for faceplate work or when tool marks are to be removed.

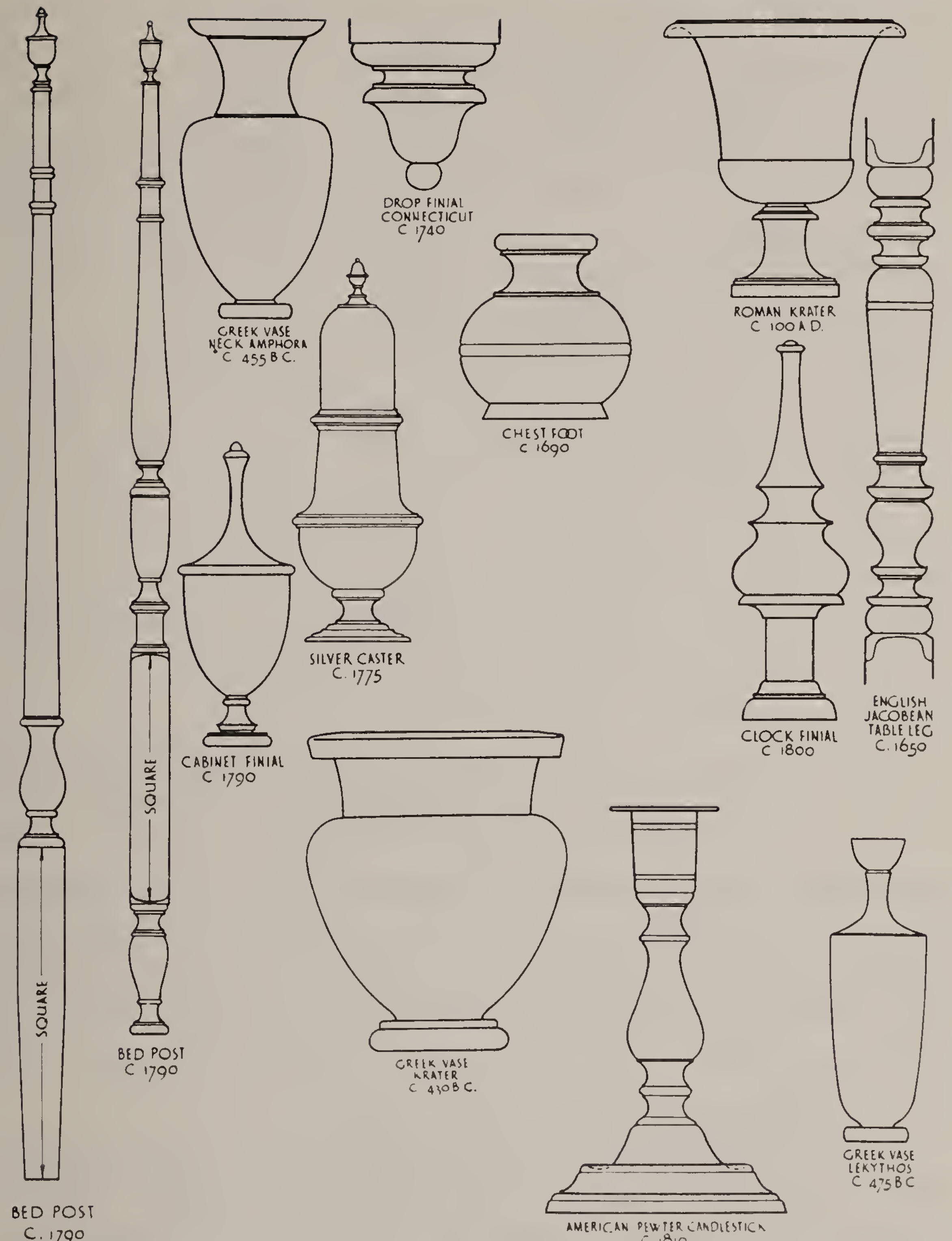


Fig. 42. Examples of antique turnings collected from remote periods of antiquity up to early nineteenth century. While all of the patterns are of turned form, some were made in clay on the potters' wheel, some were cut in metal and wood on the lathe, and some were carved with chisel and mallet from stone. Whatever the original material, each design is suitable to adaptation in other materials.

For getting into vee-cuts and hollows, fold the sandpaper twice so as to stiffen it. Examine the work carefully for small blemishes and open pores in the wood, and if necessary, rub the surface with a prepared filler. There are various types of prepared fillers on the market made from China clay and whiting mixed to a paste in

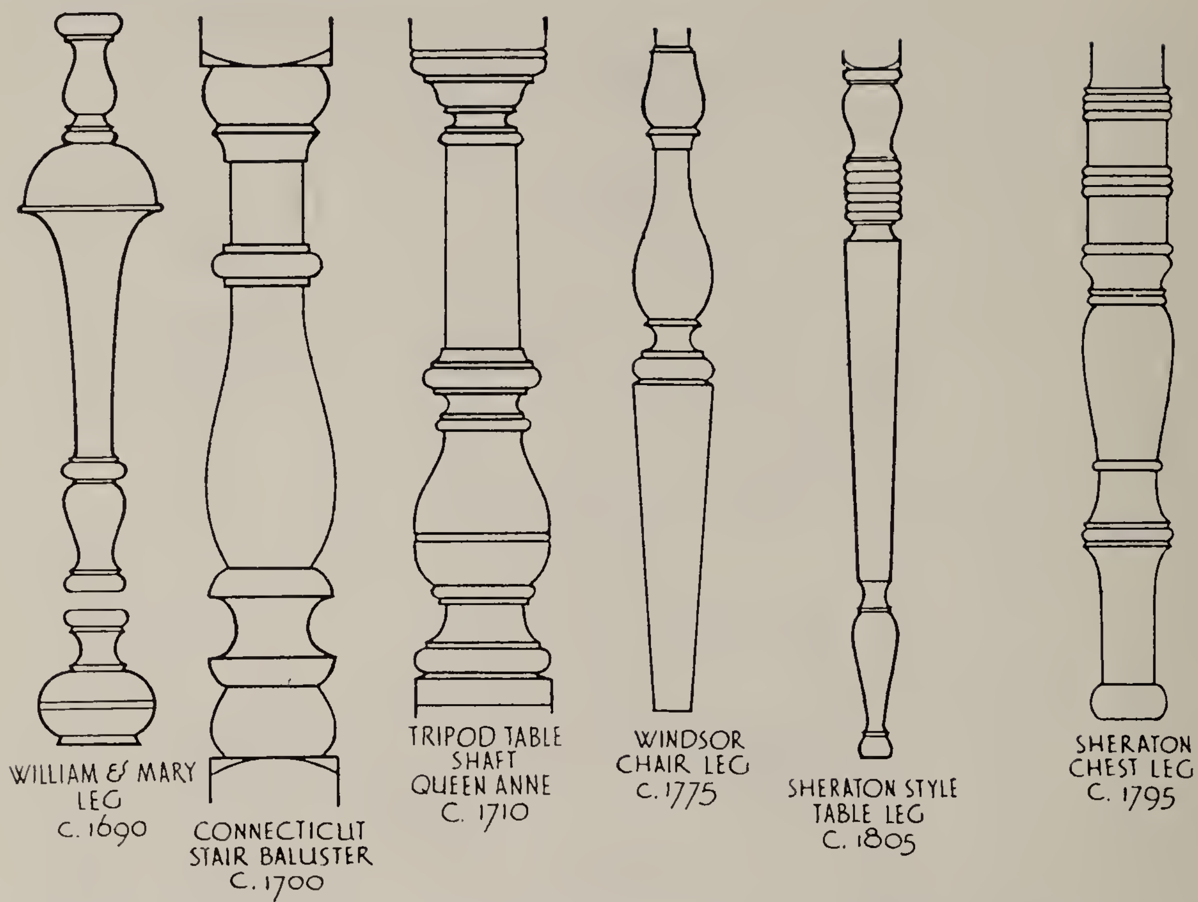


Fig. 43. Examples of antique woodturning collected from remote periods of antiquity up to the early nineteenth century.

turpentine. The preparation is applied to the surface of the wood by a small pad or rag and is well rubbed in, working as far as possible across the grain. When finished, set aside to dry for 8 to 10 hours. There are several methods commonly used to give additional finish to the work, one of the most common of which is an application of *French* or *wax polish.*

French polish is a prepared clear finish made up of shellac dissolved in methyl alcohol. This shellac comes from India and is the resinous secretion of the lac bug found on certain trees in India and Thailand. It is usually made in two grades, *orange shellac* and *white shellac* (which is bleached orange shellac). To French-polish a piece of work, rub it with a pad consisting of a cotton, wool or other soft clean rag, carefully folded to give one flat side and which acts as the carrier of the polish. When charged, an outer covering of clean linen is carefully wrapped around it, giving an unwrinkled cover to the flat surface.

Apply the flat surface of the pad to the work in the lathe, revolving it slowly by hand and covering the whole surface of the wood with a circular movement while at the same time gently

squeezing the pad. When the polish has all been transferred to the surface of the wood, the correct procedure is to remove the outer cover and recharge the center pad; a small amount of polish, however, poured on the outer cover and allowed to soak in has been found equally satisfactory and will also save time. Continue polishing to the desired finish.

Wax polishing is an alternative finishing method, using beeswax, paraffin, or carnauba wax. Rub the wax well into the wood with a soft rag or pad and allow to harden for about an hour. Then start the lathe and friction-polish with a clean dry rag. A lustrous result can be obtained by this method, although it may require several coats of wax to attain it.

Very artistic effects can be obtained on oak and some coarse-grained woods by tinting the filling medium with a small amount of stain applied as previously described and then sandpapering the surface well. The grain will then retain the colored filler and when the work is French-polished, a tinge of color which varies with the lighting will result.

Another method of finishing oak is to "fume" it with ammonia, which gives an artificial impression of age. This consists of placing the article to be fumed in an airtight box or container with a saucer of the liquid ammonia below it; or the liquid ammonia may be applied with a brush. To obtain the desired effect several coats may be necessary. A strong ammonia solution will give a dark

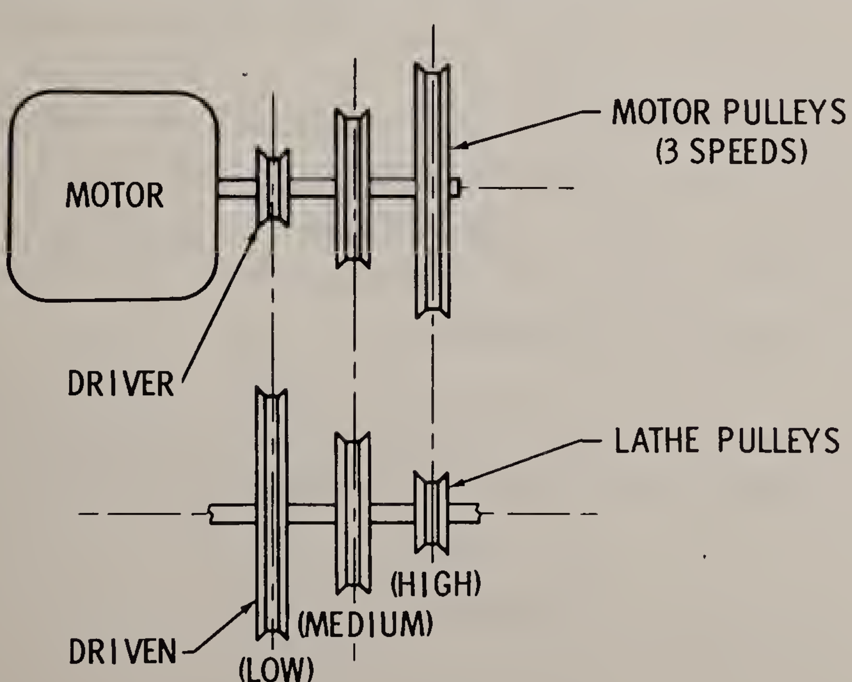


Fig. 44. Typical speed-selection arrangement of motor and lathe pulleys as usually employed with constant-speed motors.

color effect. If desired, the work can be French-polished or waxed after fuming.

Proper Cutting Speeds—Much of the success in woodturning depends upon the choice of the cutting speed. Too slow a speed not only wastes time but leaves a rough finish, whereas too high a speed may burn the tool. A typical setup for lathe speed regulation is shown in Fig. 44. It should be noted that the smallest pulley on the motor faces and drives the largest pulley on the lathe shaft.

By shifting the belt into any of the three positions shown, a variation of the speed on the lathe shaft will be obtained, and hence on the work to be turned, while the motor speed remains constant. In the case of most fractional horsepower motors, the speed is usually in the neighborhood of 1,750 rpm. To find the diameters of pulleys (Fig. 44) to give a required speed or the speed which will be obtained from a given size of pulley, the following simple formulas may be used:

Rule I: $$N_2 = \frac{D_1 \times N_1}{D_2} = \frac{\text{Diam. of Driver} \times \text{rpm of Driver}}{\text{Diam. of Driven}}$$

Rule II: $$D_2 = \frac{D_1 \times N_1}{N_2} = \frac{\text{Diam. of Driver} \times \text{rpm of Driver}}{\text{rpm of Driven}}$$

Rule III: $$N_1 = \frac{D_2 \times N_2}{D_1} = \frac{\text{Diam. of Driven} \times \text{rpm of Driven}}{\text{Diam. of Driver}}$$

Rule IV: $$D_1 = \frac{D_2 \times N_2}{N_1} = \frac{\text{Diam. of Driven} \times \text{rpm of Driven}}{\text{rpm of Driver}}$$

In the foregoing formulas, D_1 and D_2 are the diameters of the driver and the driven pulley respectively, whereas N_2 and N_1 are the speeds (rpm) of the driven and driver respectively. From the foregoing formulas, the speed obtained may be calculated easily for any one of three belt positions.

Since there is a direct relationship between the tangential speed of the lathe spindle and the rpm of the motor, spindle revolutions per minute may conveniently be determined by the following formulas:

$$\frac{12 \times \text{SFM}}{3.1416 \times \text{D}} = \text{rpm}$$

which may be written:

$$\frac{3.82 \times \text{SFM}}{\text{D}} = \text{rpm}$$

where,

SFM is the surface feet per minute,
rpm is the spindle speed,
D is the diameter of the work in inches.

In order to simplify the selection of the proper speed for the size of work to be turned, the table (Fig. 45) will be of assistance. This table gives recommended speeds for roughing, general finish

WOODTURNING SPEEDS IN R.P.M.

Diameter	Roughing Cuts	General Finish Cuts	Fine Finish Cuts and Sanding
Up to 2″	2,072	2,700	4,000
2″ to 3″	1,270	1,270	2,072
3″ to 4″	805	1,270	2,072
4″ to 5″	685	1,270	1,270
5″ to 6″	685	805	1,270
6″ to 7″	500	805	1,270
7″ to 8″	500	685	805
8″ to 9″	418	500	805
9″ to 10″	418	500	685

Fig. 45. Table giving woodturning speed for various diameters of work.

cutting and fine finish cuts and sanding for various work diameters. It should always be remembered that it is the largest diameter of the work which determines the lathe spindle speed. The speeds shown in the table are obtained with a 1,750-rpm motor, and are approximate only, because belt slippage and certain other conditions affecting spindle speeds have not been taken into account.

Miscellaneous Woodturning Tools—Apart from the previously named cutting and measurement tools, there are numerous helpful tools which, although not available in hardware supply stores, may easily be constructed to suit the various woodturning operations.

The Outside-Diameter Wood Gauge—A gauge of this type can be made easily in a few minutes' time and provides a quick and simple method of measuring and checking small diameters. It can either be used as two separate pieces or hinged at the larger end as shown in Fig. 46. It should be made preferably of ½-inch oak with a series of holes from ¼ inch to one inch in diameter accurately drilled through the center line about ½ inch apart.

Perhaps the best procedure is to cut the oak piece in two halves and plane the center edges square and straight. Place in a vise after fastening the hinge, and drill out the holes with the various diameter auger bits, holding the brace vertical and boring halfway through from each side in order to avoid splintering the lower surface. As will be noted in Fig. 46, the work is accurate as to size when the center edges are in contact at the narrow end, and there is no play between the gauge and the work. As noted in the illustration, two pieces of sheet metal fastened to each side of the arms at the hinge end will prevent wobble and make a stronger and more reliable tool.

Center-Location Gauge—A useful homemade center-finder or center-location gauge is shown in Fig. 47. To make the center finder, use a square piece of transparent celluloid or other trans-

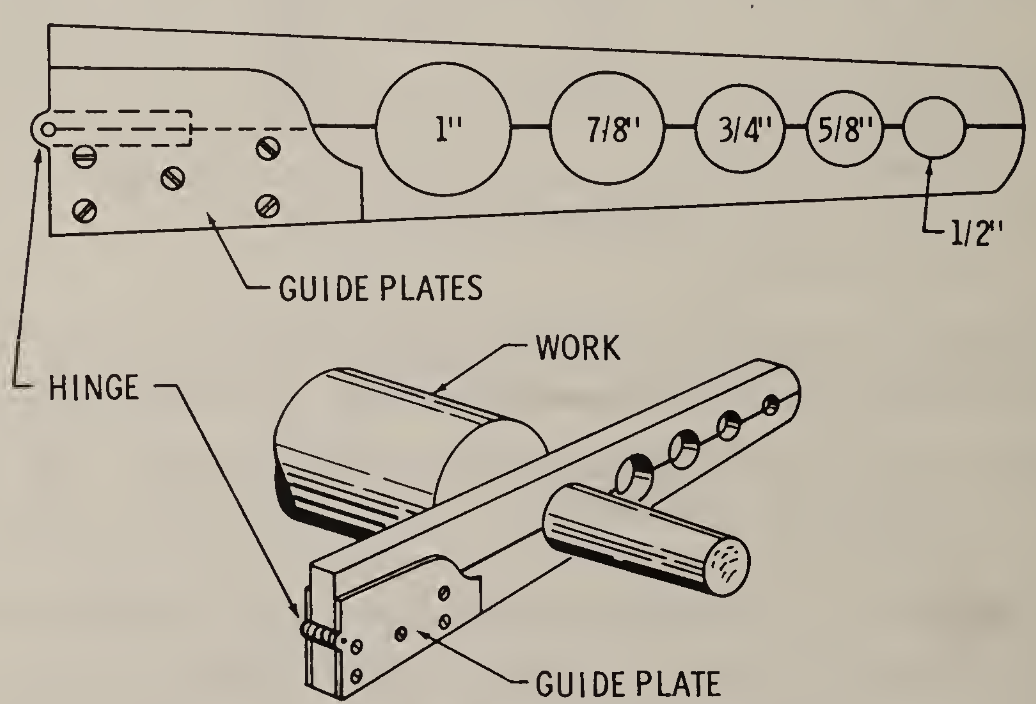


Fig. 46. Typical hinged-end, outside-diameter gauge and measuring methods.

parent material of about 1/32-inch thickness. Fasten it on a flat board at each corner and drill a small hole in its center. Then draw a diagonal line from the center hole to one corner as illustrated, and mark off on this line several half-inch spaces starting from the center. Next, remove the pencil from the compass and insert a nail filed down and sharpened to a miniature chisel edge and capable of cutting a moderately thick line.

Then inscribe a series of circles on the face of the celluloid, putting a light pressure on the cutting point, with each circle run-

ning through the previously made half-inch marks. With a small clean brush and two differently colored oil paints, fill in the circular cuts with alternate colors, wipe off surplus paint and allow to dry. The completed gauge with its series of circles may then be placed on any piece of wood to immediately enable the user to find the center, which should then be marked by a light hammer blow on a center punch.

Various Uses for the Woodworking Lathe—The modern lathe may be employed for numerous operations in addition to woodturning by the use of various attachments.

Drilling and Boring—Both these operations can be carried out on the woodturning lathe if a chuck is available for use in the headstock. To bore at right angles to the axis of a cylindrical piece, a *crotch center* must be available. When boring through a

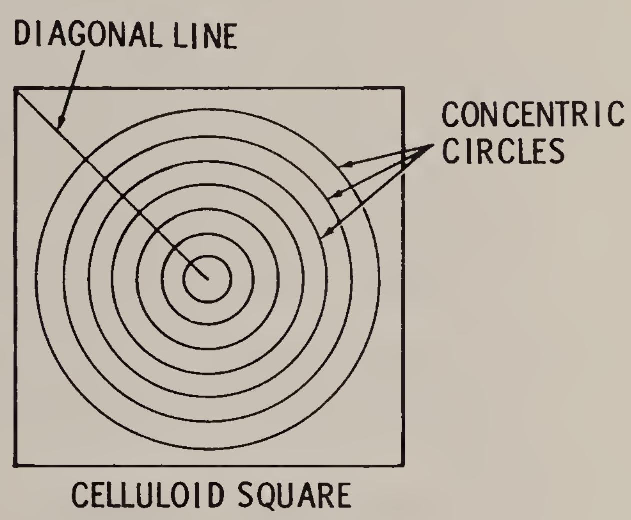


Fig. 47. Typical transparent center-location gauge.

long piece of wood having a small diameter, such as the stem of a table lamp, the best method is to revolve the piece and hold the boring tool in the chuck in the tailstock. This permits the boring tool to follow the center of rotation of the piece being bored.

Sanding—Other useful attachments for the woodturning lathe are the sanding disk and the sanding drum. The sanding drum in its simplest form consists of a sturdy cylinder on which a sheet of sandpaper is either glued or held by a stick fastened in a recess below the surface. It is mounted between the lathe centers and used for sanding curved surfaces. A sanding disk mounted on the faceplate is another useful attachment. In the absence of a faceplate, the disk can be fastened directly to the headstock by boring holes in the back of it slightly smaller than the outside diameter of the threads of the spindle. The sandpaper is secured to the

surface of the disk by glue, mucilage, wallpaper paste, or almost any adhesive material. Large sanding disks often have the paper secured by a clamp ring which has a tightening screw to hold it to the periphery of the disk.

Safety Precautions—It cannot be emphasized too strongly that any tool may be dangerous if not properly handled or operated. This is particularly true for any number of motor-operated woodworking power tools, and whereas the following refers to the woodturning lathe, certain parts of it may be applied to most other tools as well. Industrial safety codes demand the following precautions:

1. Do not wear a necktie when working on the lathe. Keep the sleeves rolled up or wear a work shirt with no sleeves.
2. Do not fail to clean, check, and lubricate all bearings and screw threads before commencing work on the lathe.
3. Do not start the motor before checking to be sure that the tailstock and tool rest are locked tight on the bed and that the wood to be turned is properly adjusted between centers. To check this, spin the work by hand.
4. Do not attempt to use a piece of wood which is cracked or split or is likely to have old broken screws or nails embedded in it.
5. Do not use the lathe bed as an anvil for riveting or hammering, and keep it wiped clean of grit with a slightly oiled rag.
6. Do not allow too great an accumulation of shavings and dust around the lathe. Stop the work periodically to check the tools, brush off the lathe, and make a fresh start.
7. Do not discard shavings or rubbish until it is ascertained that there are no small tools such as screwdrivers, calipers, etc., among it.
8. Do not run the driving belt too tight or too slack.
9. Do not attempt to obtain good work when using blunt or dull tools. Properly sharpened tools are essential for all woodturning operations.
10. Do not take your mind off the job while the lathe is running. If you must talk to someone, stop the lathe immediately.
11. Do not attempt to take too deep a cut. Hand-shape the wood

to be turned as nearly symmetrically as possible before mounting between the centers. This avoids vibration and strain on the lathe.

12. Do not attempt to adjust the tool post while the lathe is running. After setting it, revolve the work by hand to see that proper clearances are provided.
13. Do not place the spur center in the spindle and then hammer the wood into it. This may damage the headstock and bearings.

CHAPTER 15

The Jointer and The Shaper

The jointer has one cutterhead located below the table and the feed is usually by hand. Its primary use is to cut a true face and edge on stock that has been warped or twisted or has other irregularities. The table is in two sections; the infeed section is raised or lowered to control the thickness of the cut, whereas the outfeed part of the table is raised or lowered as a unit to control the accuracy of the finished piece. By tilting the fence, bevel edges can be cut. This machine can also be used for tapering, end planing, and rabbeting.

Construction—The essential parts of a jointer are a substantial *base* or frame supporting the assembly, *cutterhead*, *tables* or beds, *guide fence*, and table-adjusting *handwheels*. The cutterhead, which is the heart of the machine, houses two or more high-speed steel knives. It revolves in a rotary motion between the front or infeed table and the rear or outfeed table. The tables are adjustable, that is, they may be raised or lowered by means of handwheels to regulate depth and accuracy of cut. A guide fence extending along both tables is provided against which the work is held as it is advanced toward the cutting knives. It may be tilted 45 degrees each way and may also be moved crosswise along the jointer table. The cutterhead is provided with a guard cover as a safety measure.

The speed of the cutterhead is usually between 3,600 and 6,000 rpm, although for certain types of work a speed up to 8,000 rpm is used. Since the speed of the conventional 60-cycle AC motor is 3,450 rpm or less, various types of gears and pulley ratios are employed to obtain this higher speed.

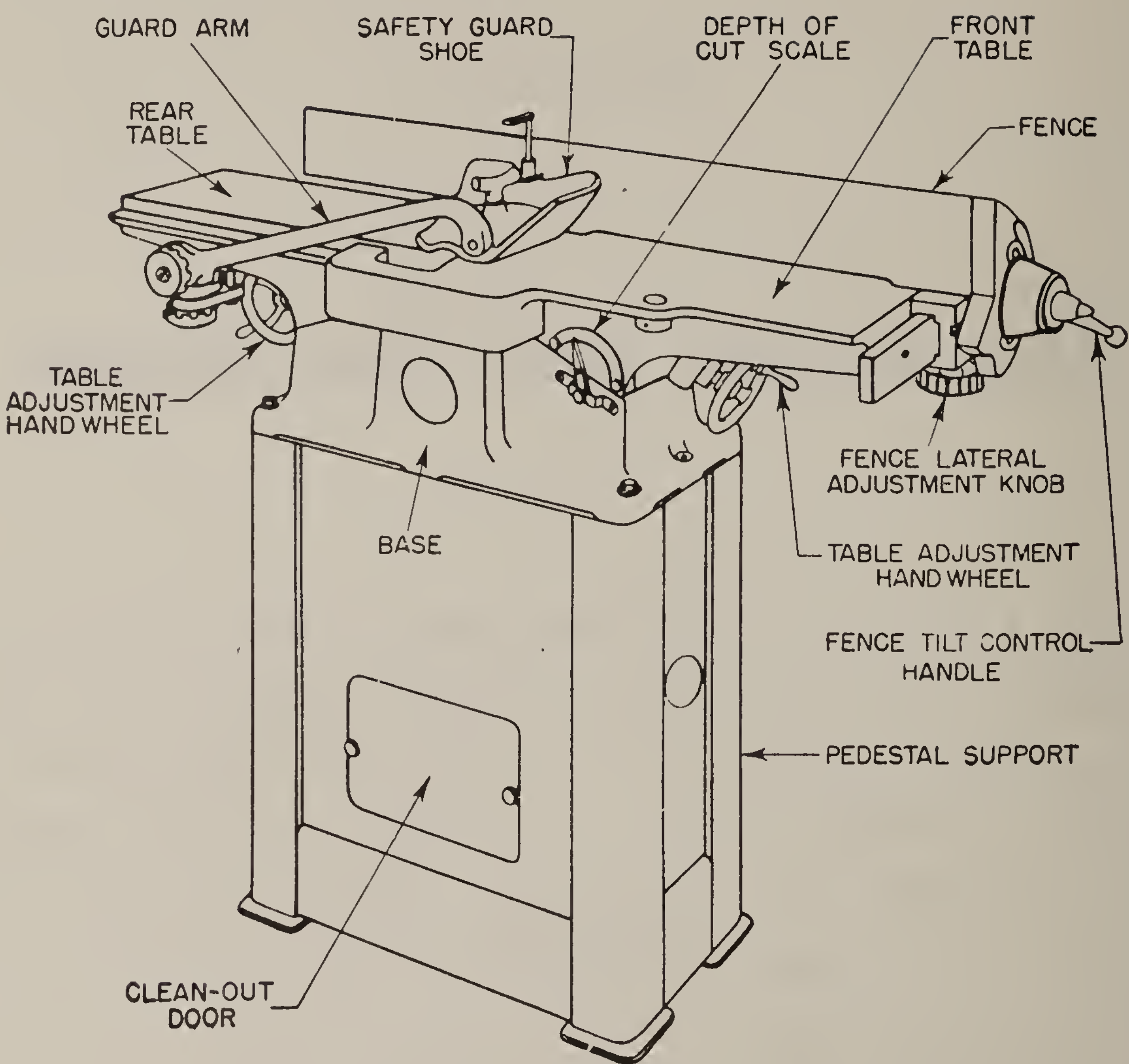


Fig. 1. Typical 6-inch jointer equipped with a dual-purpose safety guard and hold-down shoe. Rear knife guard is hinged to the back of the fence, and covers the pulley and knives as the fence is moved over. The solid steel cutterhead is of the three-knife type, each knife being held by four jack screws and a chip breaker. The aluminum fence is movable laterally to full table width for rabbeting and is indexed by a plunger at 45 and 90 degrees. It is controlled by lock handles. Depth of cut is shown on the indicator in fractions of an inch. The cutterhead revolves at a speed of 3,900 rpm thus making 3 × 3,900 or 11,700 cuts per minute.

Adjustments—One of the most important adjustments on the jointer is the relationship of the outfeed table to the cutterhead. To do satisfactory work, the outfeed table must be exactly level with the knives at their highest point of rotation. To make this adjustment, instructions issued by the manufacturer of the equipment should be followed.

The infeed table, on the other hand, must be somewhat lower than the rotating knives, the exact height depending upon the depth of the cut. It follows that the difference in height between the two tables is equal to the depth of the cut. It should also be

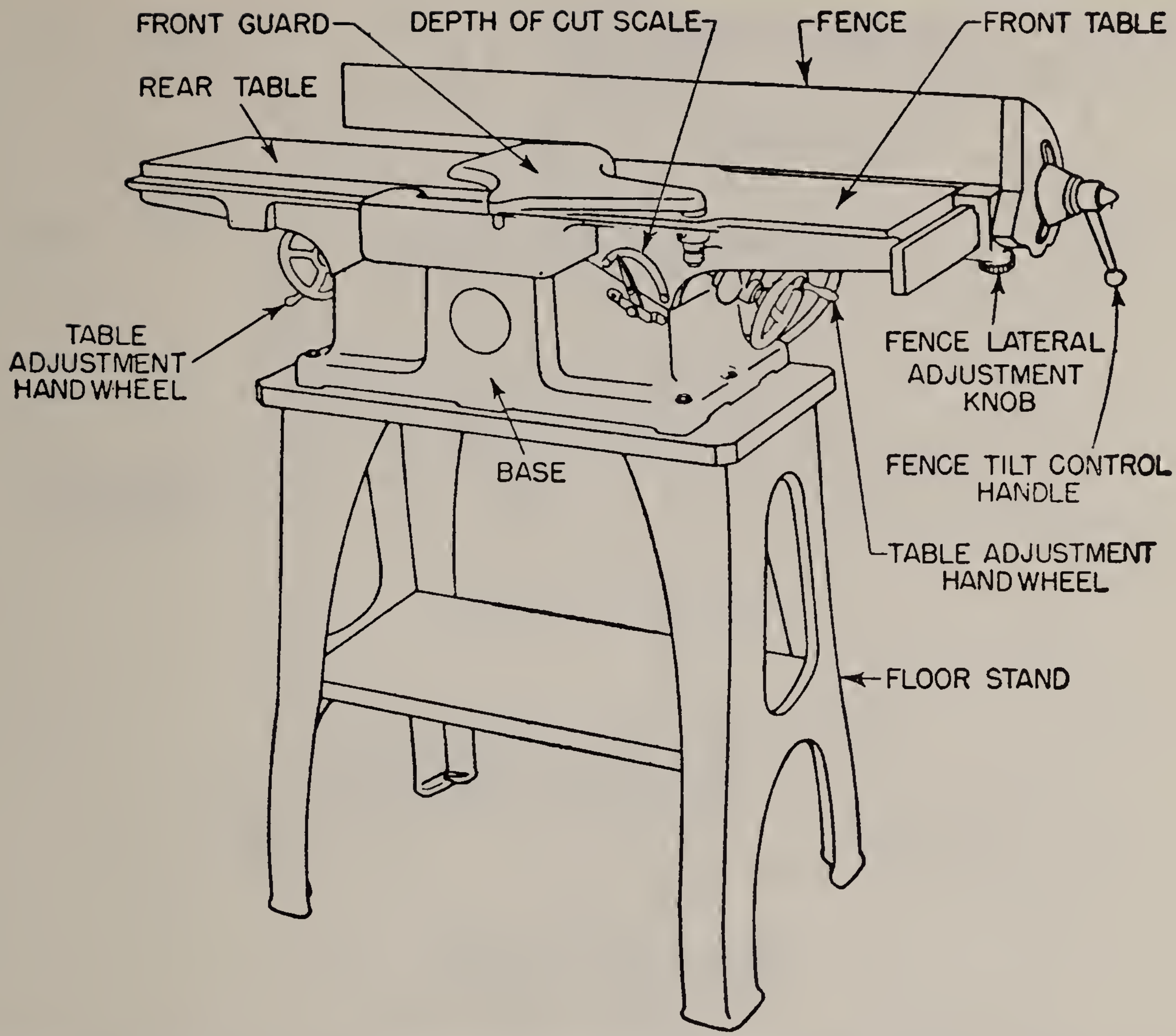


Fig. 2. Typical 6-inch jointer with flat-type guard. A flat-type guard provides protection in front of the fence. The rear knife guard attaches to the back of the fence to cover the pulley and knives as the fence is moved over.

observed that improperly adjusted tables will result in the work being cut on a taper.

When knives become dull or nicked, it is necessary to replace them with a new set or to sharpen them. Jointer knives may be sharpened and brought to a true cutting circle by jointing their edges while the cutterhead is revolving. In performing this operation, a fine-cutting oilstone is placed on the outfeed table, and the table lowered until the knives just touch the stone at their highest point of rotation.

There are numerous other methods used in sharpening jointer knives, each having its particular advantage, depending upon the knowledge and experience of the operator. When it becomes necessary to replace or reset the knives in the cutterhead, manufacturer's instructions should be followed, because different cutter-

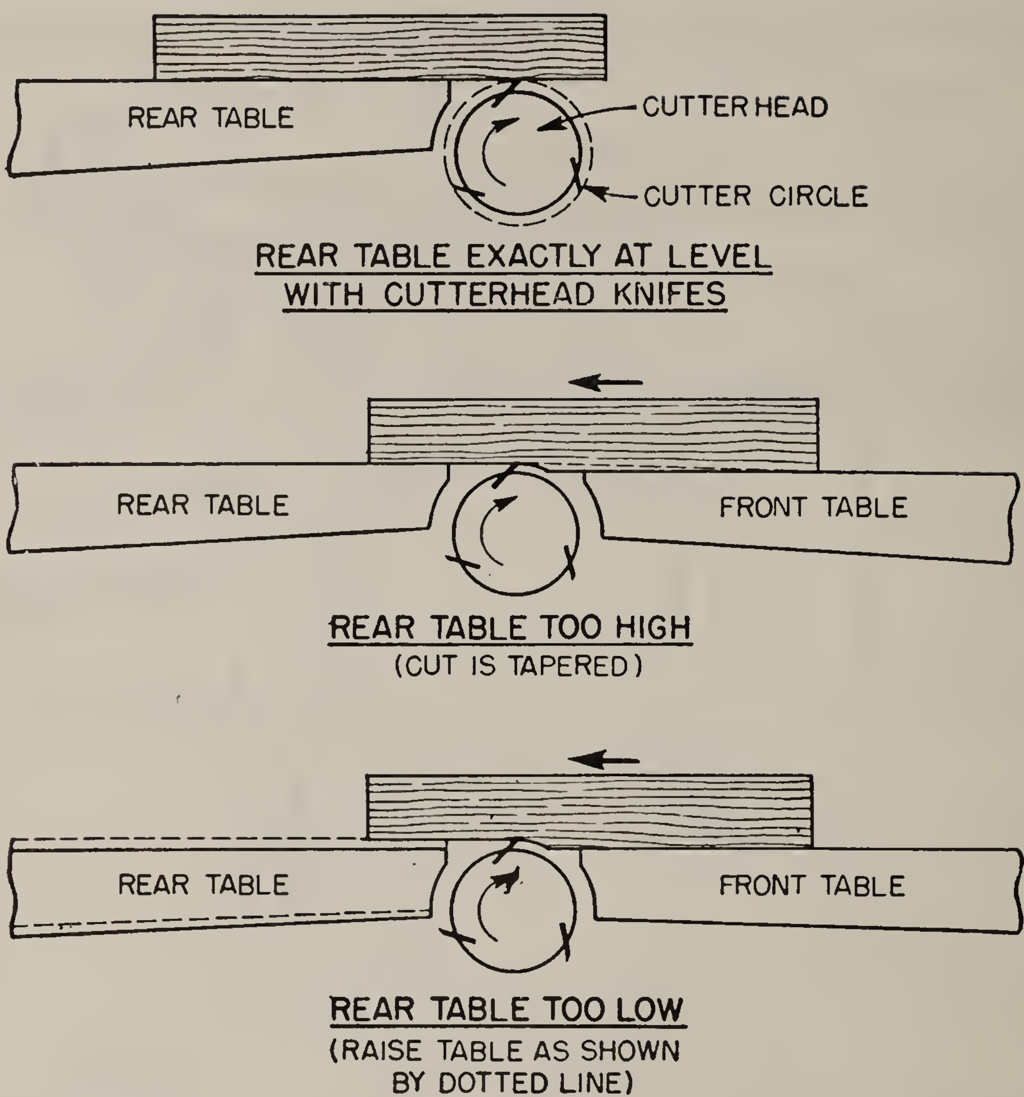


Fig. 3. Outfeed-table adjustment on the jointer. In order to do satisfactory work, the rear or outfeed table must be adjusted to be exactly level with the knives at their highest point of rotation. The front or infeed table must be lowered slightly, the amount being equal to the depth of cut.

heads have different knife-holding methods. Proper installation of the knives is the first essential to proper performance of the jointer.

Operation—Although a great number of woodworking operations may be performed on the jointer, the most common are: *edge planing, planing of ends, surfacing* or *planing a working face.* Among these, edge planing or jointing an edge is the simplest and most common operation. Assuming the machine to be properly adjusted and the guide fence to be square with the table, the jointer is placed in operation by feeding the work over the rotating cutterhead. The hand over the rear or outfeed table presses the work down so that the cut surface will make good contact with the table. The hand over the front or infeed table exerts a small amount of downward pressure, and advances the work over the cutterhead. Pressure is increased on the outfeed table as the work

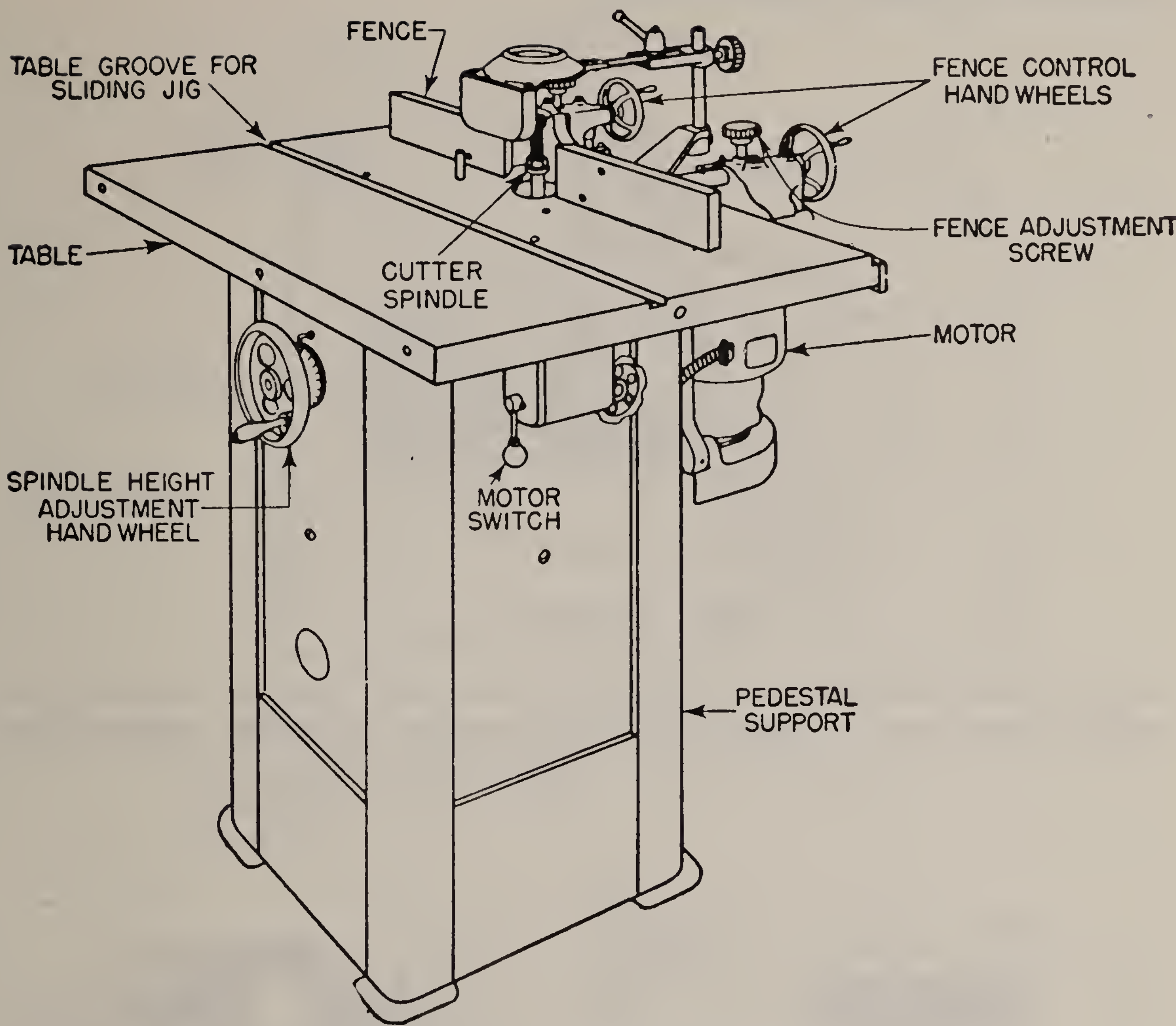


Fig. 4. A typical shaper.

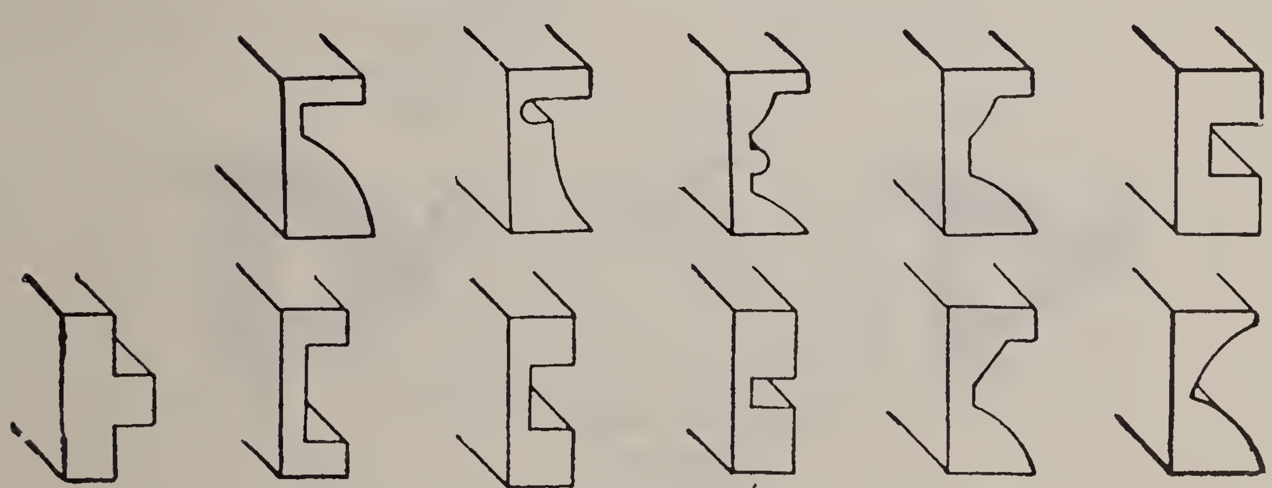


Fig. 5. Various types of shaper cuts.

is advanced. Both hands, however, exert side pressure on the work toward the guide fence to obtain the proper edge.

Edges on thin work such as veneer or similar products may also be planed on the jointer, provided the work is held firmly between two suitable boards. In most edge-planing operations of this type, however, special clamps are used to hold the work in

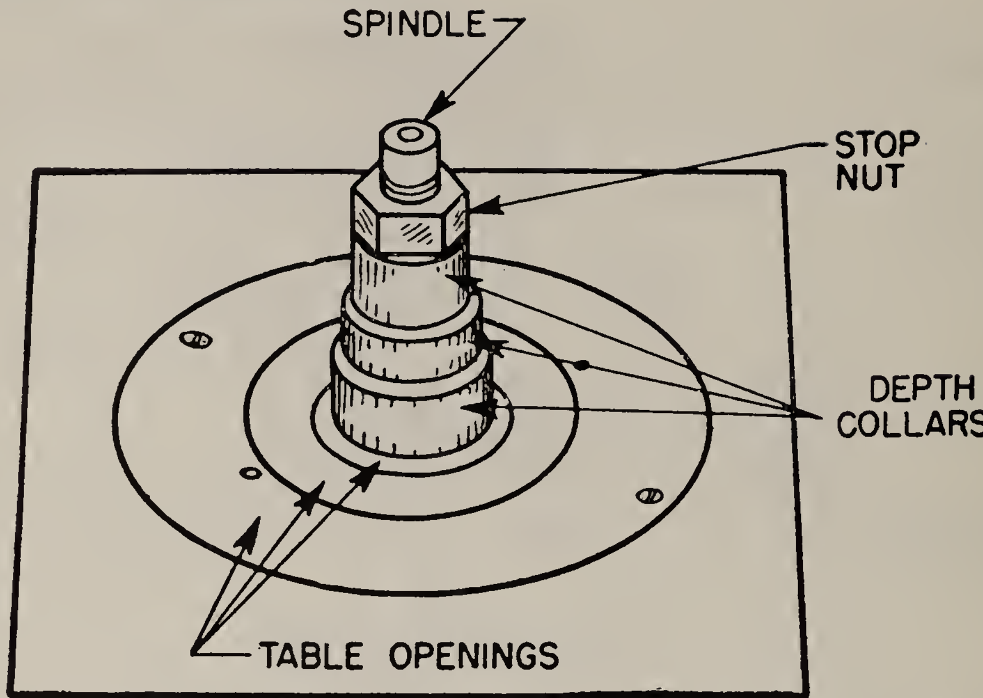


Fig. 6. Shaper spindle projecting through the table opening. Note how the table opening may be adjusted by the insertion of proper nesting rings.

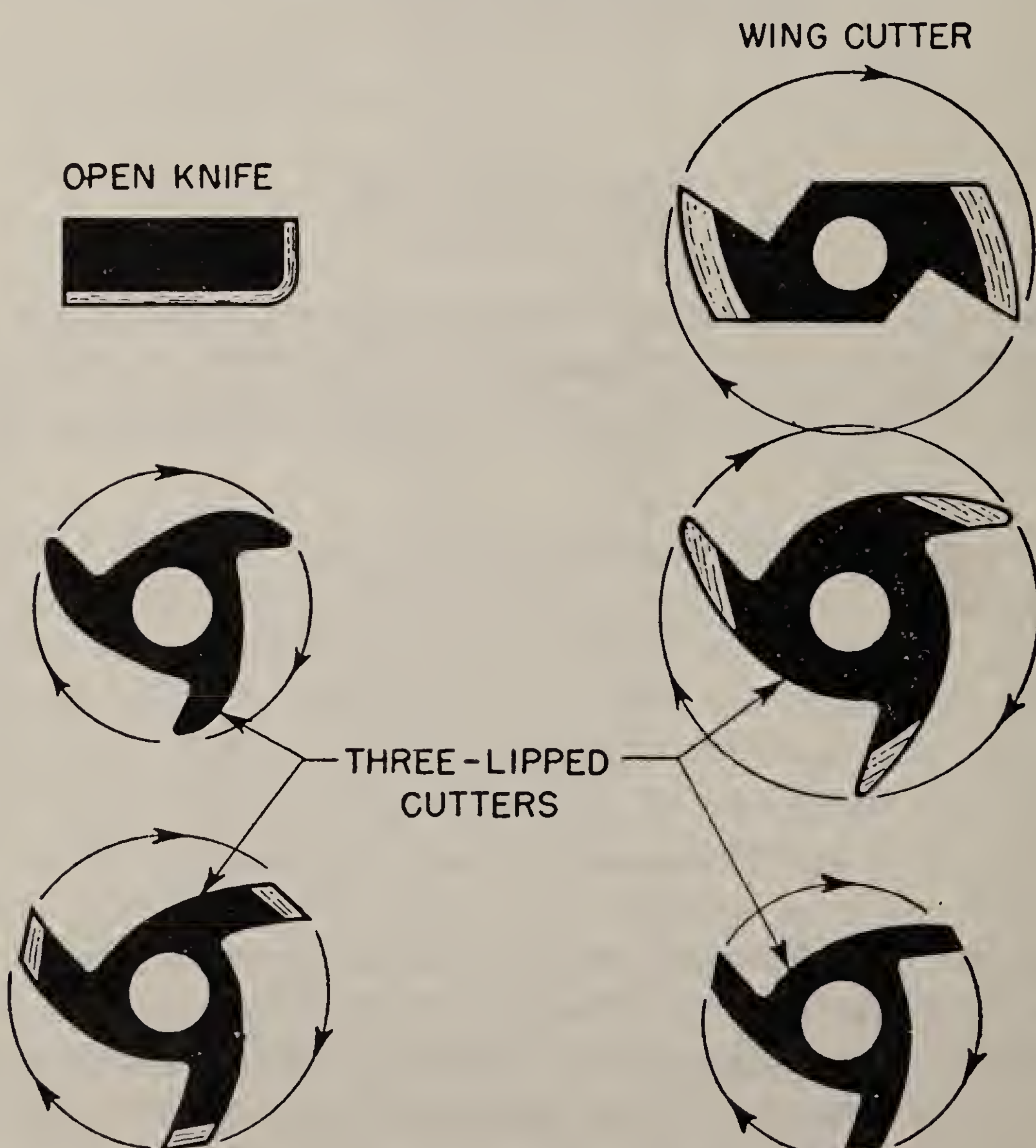


Fig. 7. Various types of shaper cutters used in shaper operation.

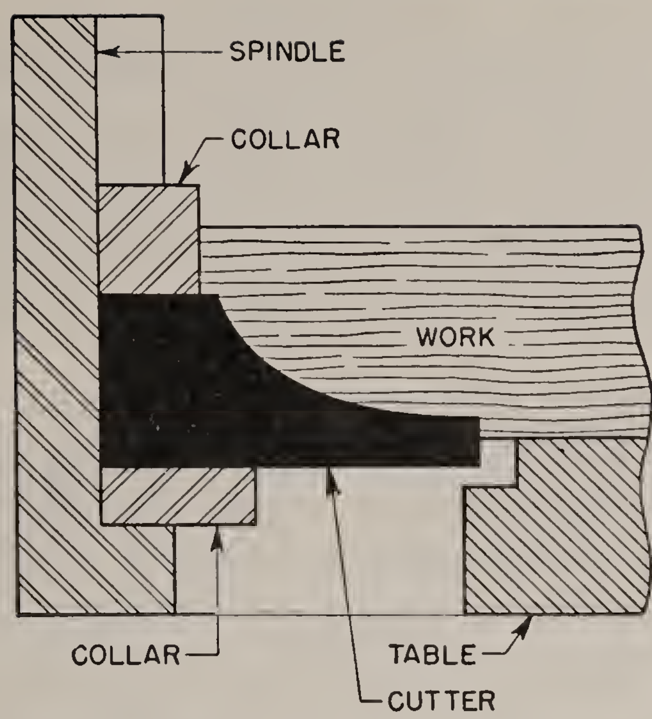


Fig. 8. Section through shaper spindle and action of cutter when shaping against collar in typical shaper operation.

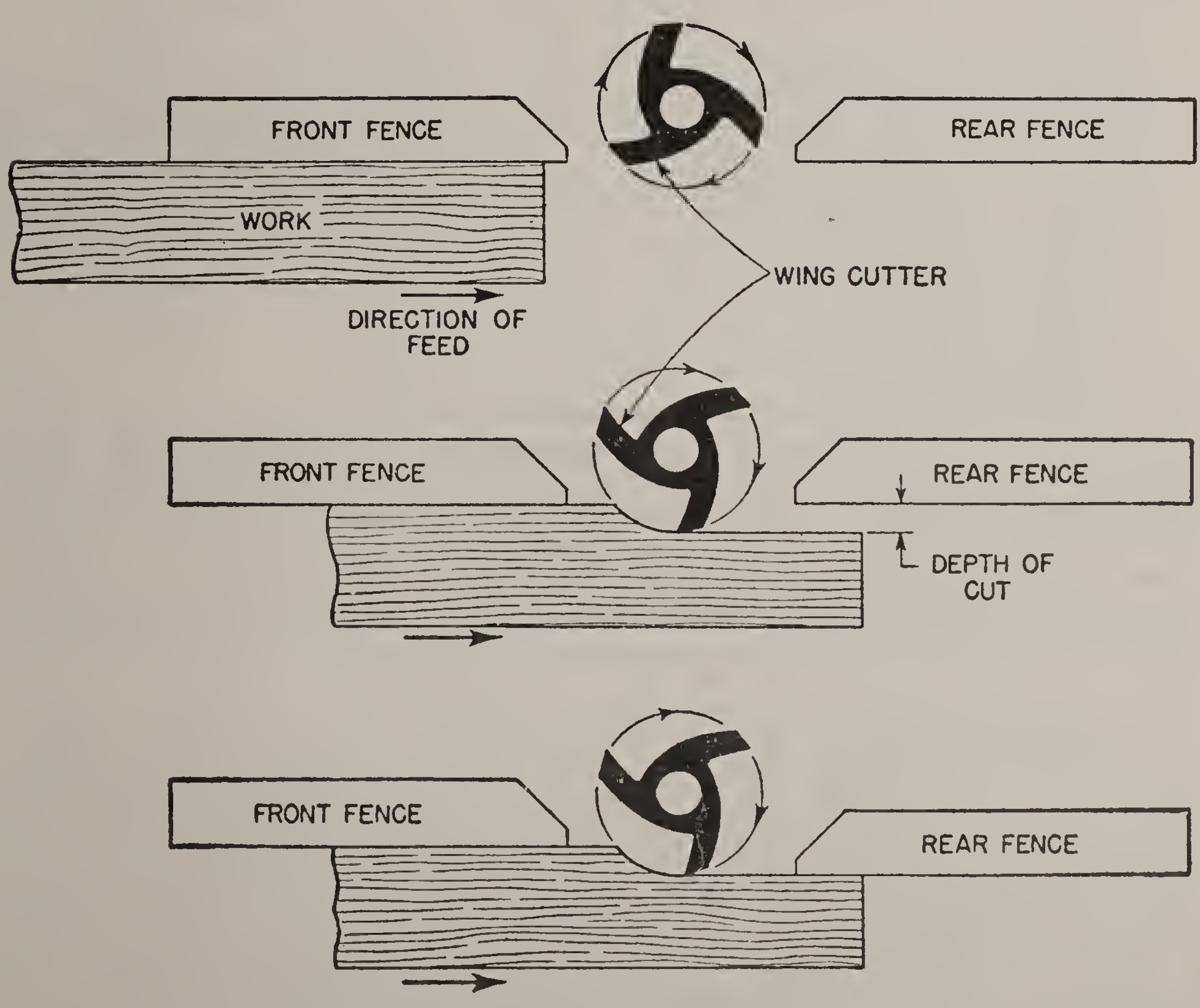


Fig. 9. Shaper fence adjustment to depth of cut. The rear fence is usually set to the exact depth of the cut prior to the actual operation.

place. Planing the end grain of a board may be performed in a similar manner to planing with the grain. The necessary precaution consists of taking only light cuts each time, because of the tendency of the grain at the end of the board or boards to split when thick cuts are attempted.

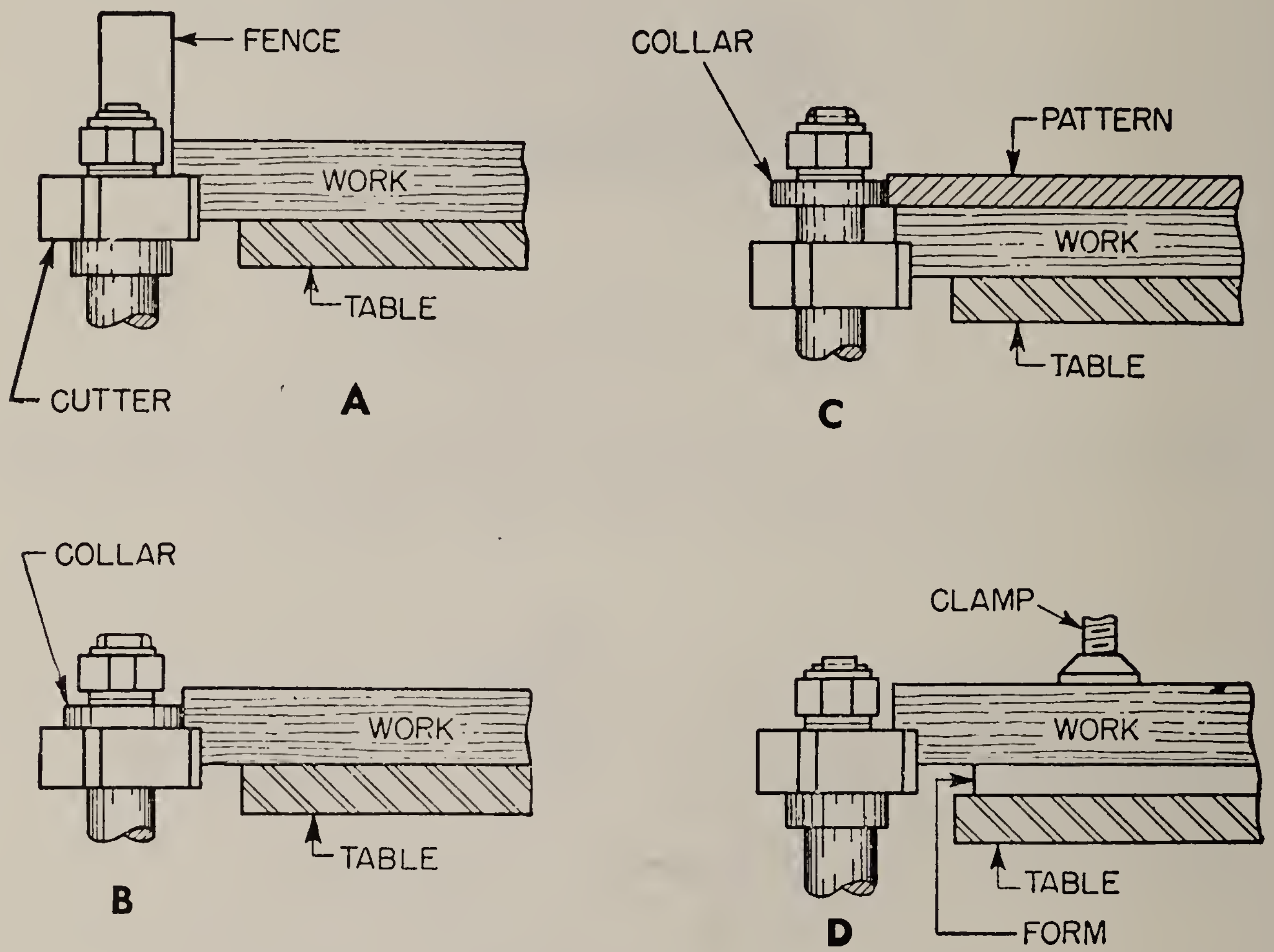


Fig. 10. The four principal methods used in holding the work against the shaper knives. (A) The work being held against the fence or guide as required. (B) The work is being shaped against a collar. Here the rim of the collar rides against the work thus limiting the depth of cut. (C) Shaping with an outline pattern. When this method of shaping is used, the pattern rides against the collar to determine the depth of cut. (D) The shaping operation is performed with the aid of a form. The function of the form is to hold the work in position so that it can be advanced to the shaper cutter.

To avoid splitting the end grain, some operators make only a short cut at one end, then reverse the wood and complete the planing from the opposite edge. Face planing or planing the sides of a board is one of the more difficult jointer operations. When planing the faces of a board the grain pattern in the edges should be noted; in order to plane the board with the grain, the two faces of the board must be planed in the opposite direction. If the face grain fails to plane smooth, try the opposite direction.

SHAPER

The shaper is used for rabbeting, grooving, fluting, and shaping of every description. The shaper consists essentially of a vertical spindle with a *cutterhead*, *table*, *fence*, and *base*. Generally, a knife with a cutting edge ground to the desired shape of cut is used, but solid cutters milled to the desired shape are also available.

Stock may be cut roughly to shape with a band saw or jigsaw before being finished on the shaper. When a number of pieces of the same pattern are to be shaped, special templates are often used to regulate the depth of cut by bearing against the shaper collar.

Construction—Shapers are usually constructed with a vertical spindle which carries the cutterhead. The spindle with a suitable

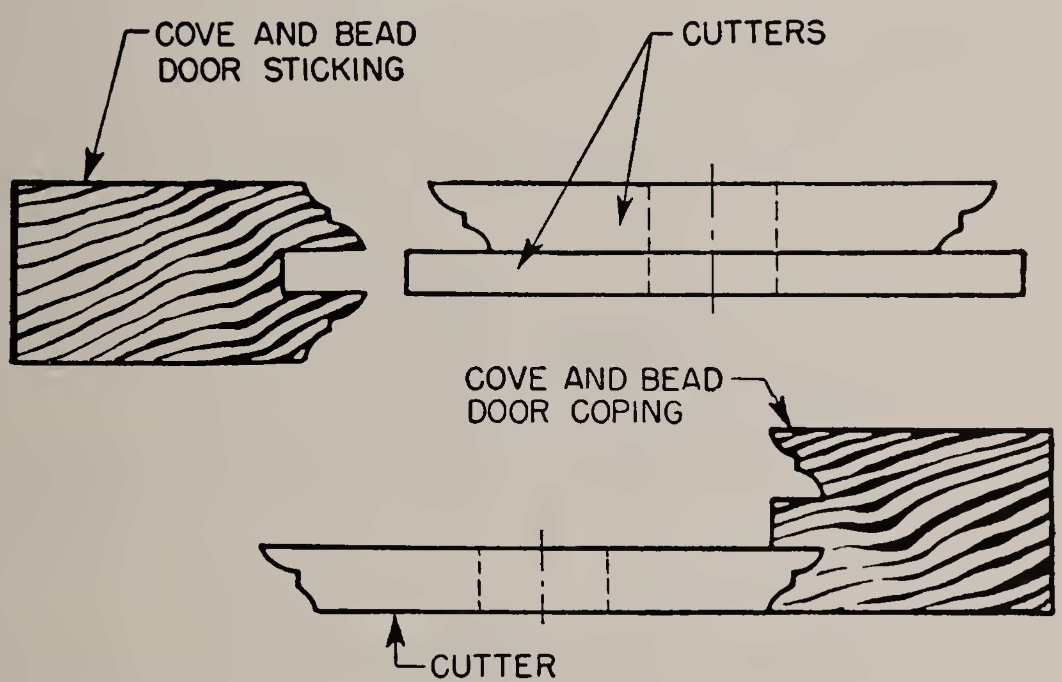


Fig. 11. Cutter types used for shaping typical cove and bead moldings and copings.

knife attached projects above the surface of an accurately planed table, and the cutting edges of the knife revolve at a very high speed. Modern machines have a spindle speed of 5,000 to 10,000 rpm. Because of this high speed, pulleys of about three-to-one ratio are generally necessary when the machine is driven by the conventional 60-cycle AC motor. On some machines a reversible motor may be used. In some units the motor is reversed by means of a lever fitted directly to the motor, whereas others use a reversing switch fastened to the side of the shaper stand and wired to the motor.

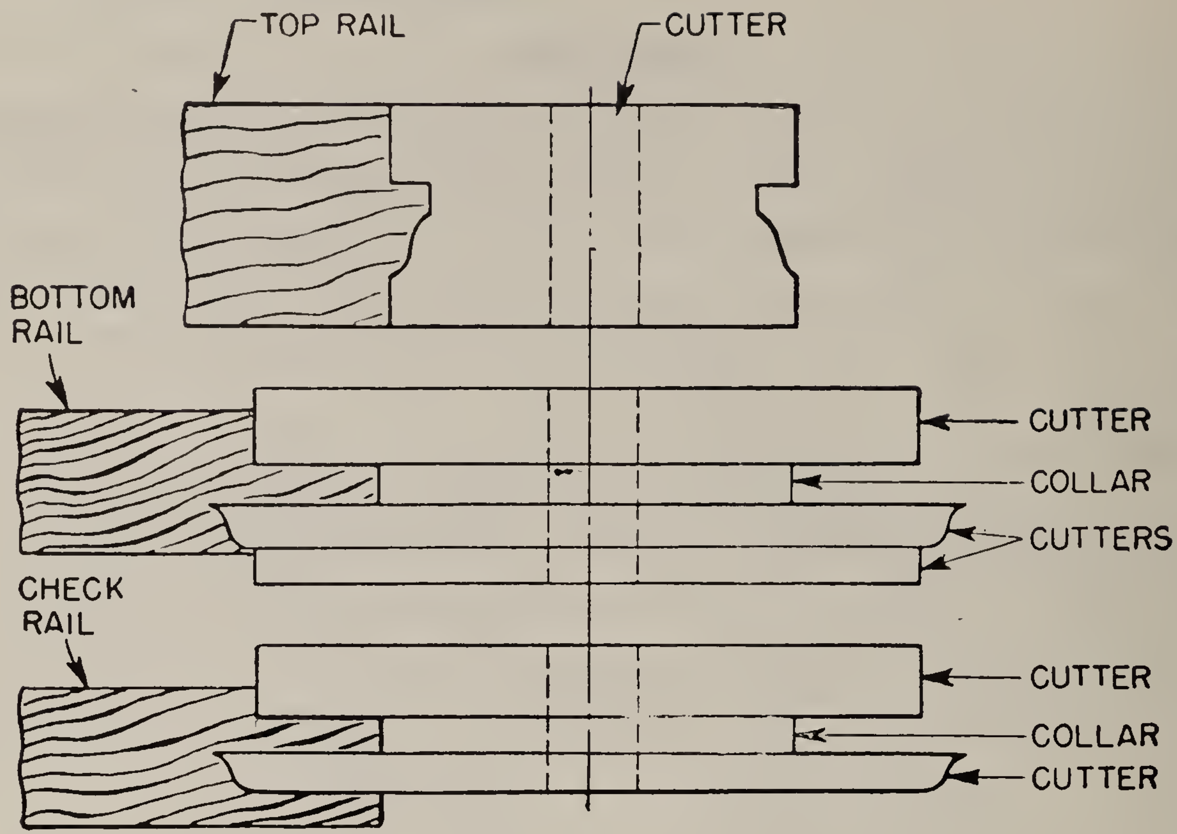


Fig. 12. Cutter types and method of collar spacings for shaping typical window sash.

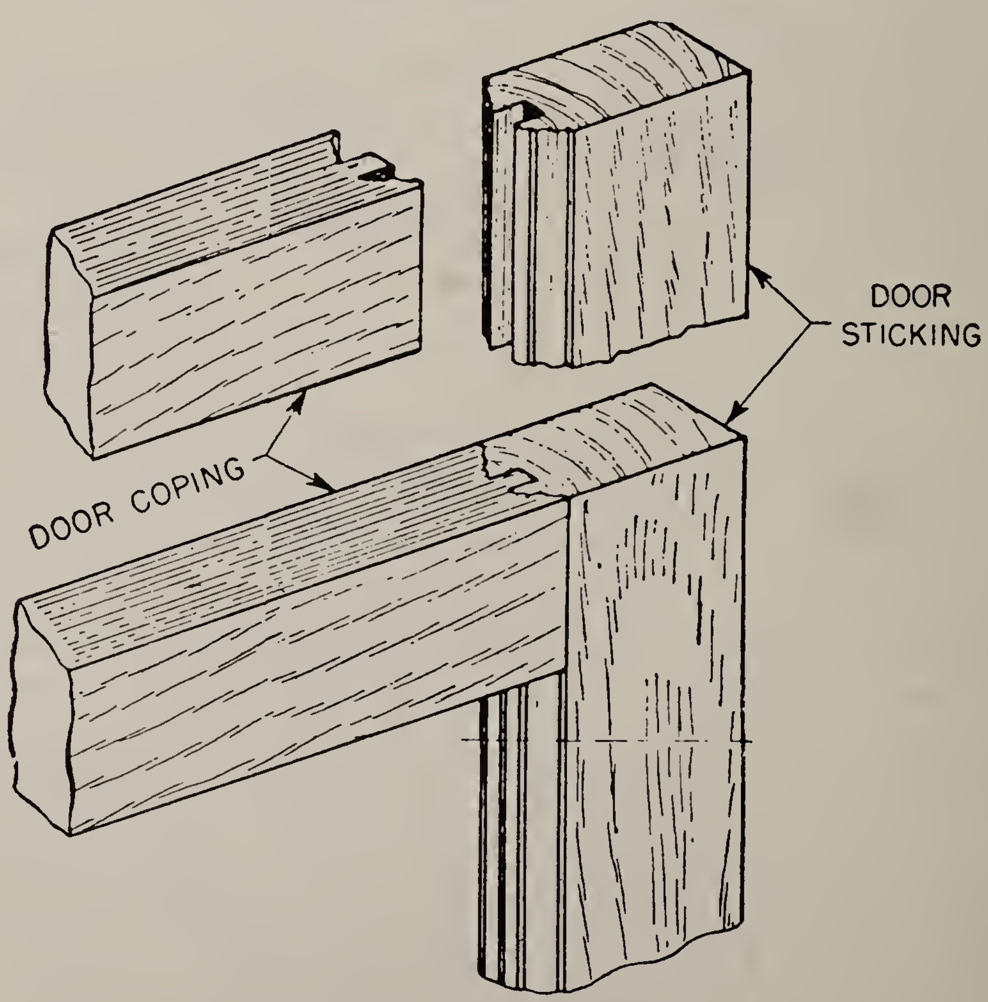


Fig. 13. Typical door assembly.

A wide variety of knives, collars, etc., are used in shaper operations. Shaper knives are of two kinds, the open-face or flat knives and the three-lip cutters. The flat knives are used mainly on large machines. The three-lip shaper cutters have three cutting edges and slip right over the spindle. Since it is impossible for them to get loose, these are much safer to work with.

Operation—There are four main methods used for holding or guiding the stock against the shaper knives. They are:

1. Shaping with guides or fences.
2. Shaping against collars.
3. Shaping with an outline pattern.
4. Shaping with forms.

Each of these methods is widely employed and each is suitable for a certain kind of work. In many instances where a job calls for working the stock directly against an ordinary shaper collar, the

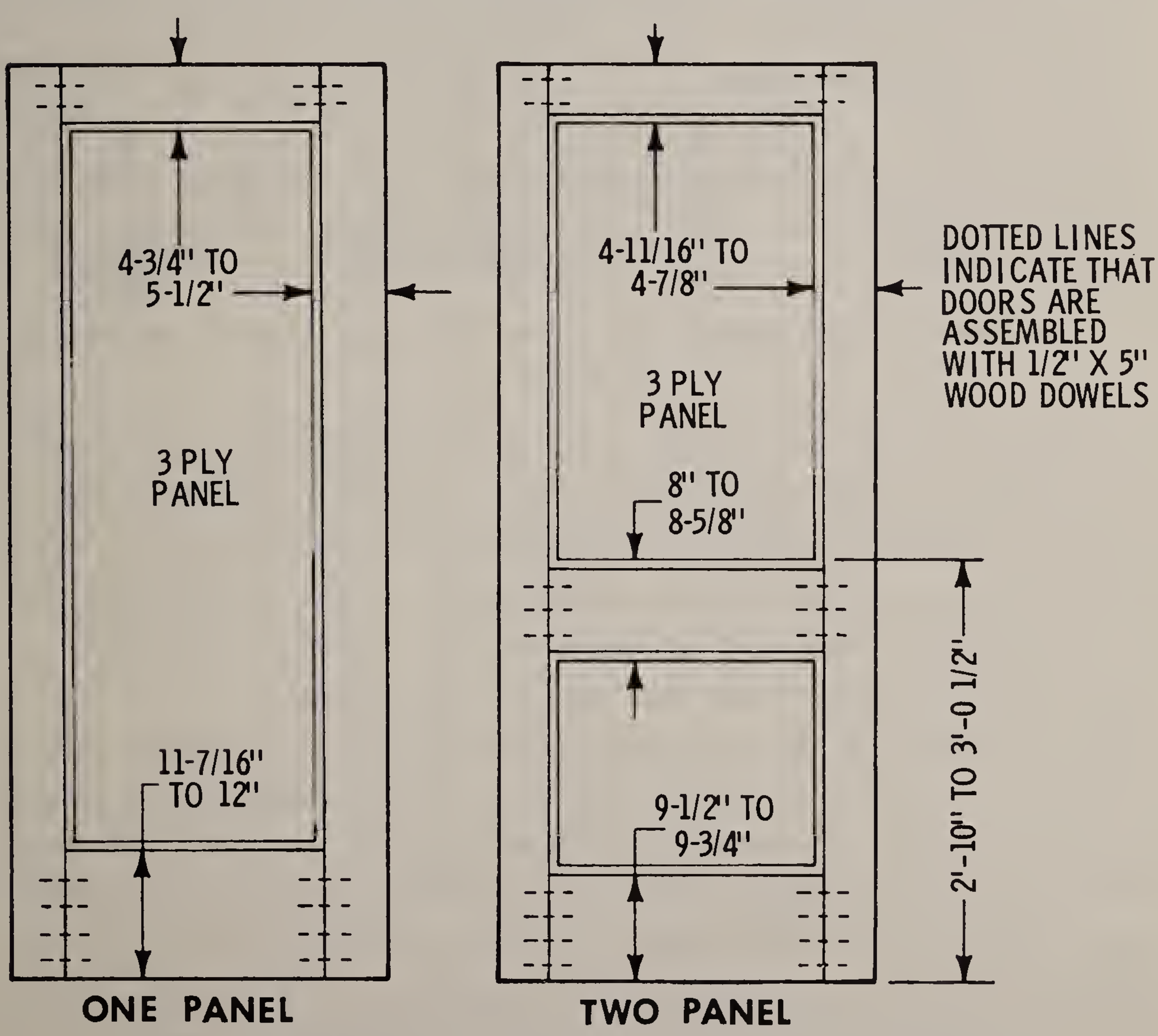


Fig. 14. Dimensions of typical one- and two-panel doors.

friction created between the collar and the work has a tendency to burn and mar the material. This burning is readily avoided, however, by the judicious use of ball-bearing guide collars in place of

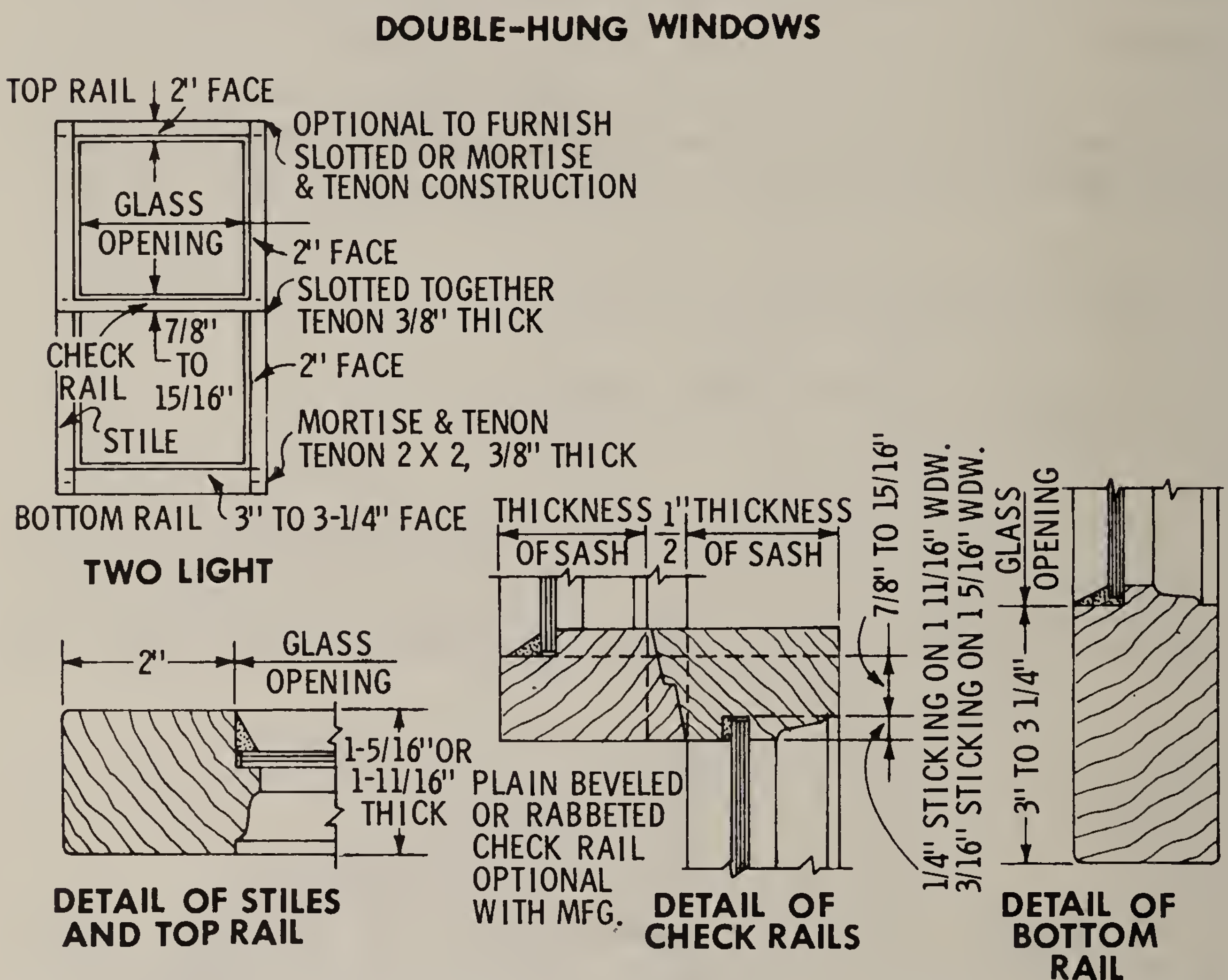


Fig. 15. Construction details and dimensions of typical double-hung windows.

the regular type of unit. As the outer shell of the ball-bearing collar is free from the slotted collar proper, it revolves independently of the latter when the pattern or stock comes in contact with it. Also, the ball-bearing collar has the advantage in that it rolls along with the feed, thus practically eliminating all wear and friction on forms, guide patterns, and material being shaped.

Heavy cutting is best accomplished with sharp knives set in open collars; these are well balanced to avoid vibration and render the setup as safe as possible. Whenever it is necessary to work directly against the shaper collar, it is well to rest the stock against a steel guide pin, while easing it slowly to the knives at the beginning of each cut. Sometimes the character of the work is such that it is impossible to employ a hold-down device, and in such

cases it is customary to take two or more light cuts where a deep cut is necessary.

When doing heavy cutting it is advisable to relieve the cut as much as possible by chamfering the corners of the stock on an angled band saw, or on a circular saw.

When shaping short and light work, strips of hardwood may serve as a guard, and a hold-down device can sometimes be employed as a fence; this is because it is readily set at any required distance from the cutters by means of the adjusting screws.

When machining curved and irregularly shaped parts, some operators use small curved fences equipped with adjusting rods which fit into the regular guard and hold-down device. They usually find this method better than working the stock against the shaper collar.

Power and Speed—The size of the motor necessary to operate a shaper depends upon the type of work to be done. The medium-sized shaper using cutters with a ½-inch bore works satisfactorily with a ½-horsepower motor. Where large knives mounted between slotted collars are used, a ¾- to 1-horsepower motor will be necessary.

The motor must be a 3,450-rpm type in order to give the shaper spindle the required speed. When the pulley ratio is 3 to 1, the actual spindle speed will be about 1,000 rpm.

CHAPTER 16

The Sander

Sanding is the use of an abrasive to smooth the surface of stock. Abrasive material is used on sandpaper as well as on grinding wheels, and it may be used as a powder. The work should always be prepared by the use of cutting tools, such as planes and chisels. The woodworker should never try to remove stock with sandpaper. The sandpaper should not be used until the stock is cut to final size, or until the whole project is put together.

Natural abrasives are found in the ground and include sandstone, flint, garnet, and emery. The most common abrasives used on sandpaper follow.

Flint sandpaper is made of sandstone or quartz. It is cheaper in price than any of the other sandpapers, but it does not last as long. It is good for hand sanding blocks.

Garnet sandpaper has a reddish-brown color and is used on sanding machines such as vibrator sanders and belt sanders. It is more expensive than flint sandpaper, but lasts much longer when used on machines or for hand sanding.

Aluminum oxide sandpaper is a manufactured abrasive used both for machine sanding and for hand sanding.

Sandpaper is sold most commonly in sheets for hand sanding and for vibrator sanders. It is sold in rolls or prepared belts for belt sanders, and in disks for disk sanders.

Flint sandpaper is sold in 9- by 10-inch sheets and in grades of extra coarse, coarse, medium, fine, and extra fine. For most work, the coarse, medium, and fine grades are satisfactory.

Garnet sandpaper is sold in 9- by 11-inch sheets and ranges from very coarse (No. 3) to very fine (No. 8/0). For most work, three grades are most commonly used: coarse (No. 1½ or 2), medium (No. ½ or 0) and fine (No. 4/0).

Aluminum oxide sandpaper is sold in 9- by 11-inch sheets which are graded in numbers ranging from very coarse (No. 30) to very fine (No. 240). The most commonly used grades are: coarse (No. 40), medium (No. 60) and fine (No. 150).

The system of numbering used in grades of aluminum oxide sandpaper is a newer system and will be adapted to garnet sandpaper as well as man-made abrasives other than aluminum oxide sandpaper. The numbering system is based upon the number of holes per inch in the sieves used to sort the abrasive grains.

Much of the sanding in the home workshop will be done by hand even though a vibrator sander or a belt sander is available. As has been mentioned, the stock should be cut to finished size with the cutting tools. In order to prepare the work for finishing, the workman usually starts with a coarse grade of sandpaper, goes to a medium grade and then to a fine or very fine grade for final preparation for finishing. This procedure can be accomplished with the machine sander, but a certain amount of hand sanding must always be done because of corners and other spaces which cannot be reached by machine sanders. Also, the machine sanders may leave certain marks which can only be removed by hand sanding. A handmade sandpaper block made to fit a quarter-sheet of sandpaper is satisfactory although commercial sandpaper holders can be purchased. All sanding should be done with the grain and not across the grain because the latter will leave scratches on the work. End grain should be sanded only in one direction, and surfaces which are to be glued should not be sanded. For curved surfaces, the sandpaper can be wrapped around a dowel or held in the palm of the hand for best results.

Motor-driven abrasive tools play an important role in the woodworking industry. They are made in several different forms, which include drum sanders, belt sanders, and disk sanders. The function of these machines is to smooth wood surfaces by the action of various types of abrasives. These abrasives, or grits, come in a wide variety of sizes, and it is general practice with any given

wood to use the correct grit that will not make scratches visible to the eye.

Belt and Disk Sander—A combination machine of this type (Fig. 1) is often found in home workshops. It is very versatile and suitable for the majority of sanding operations.

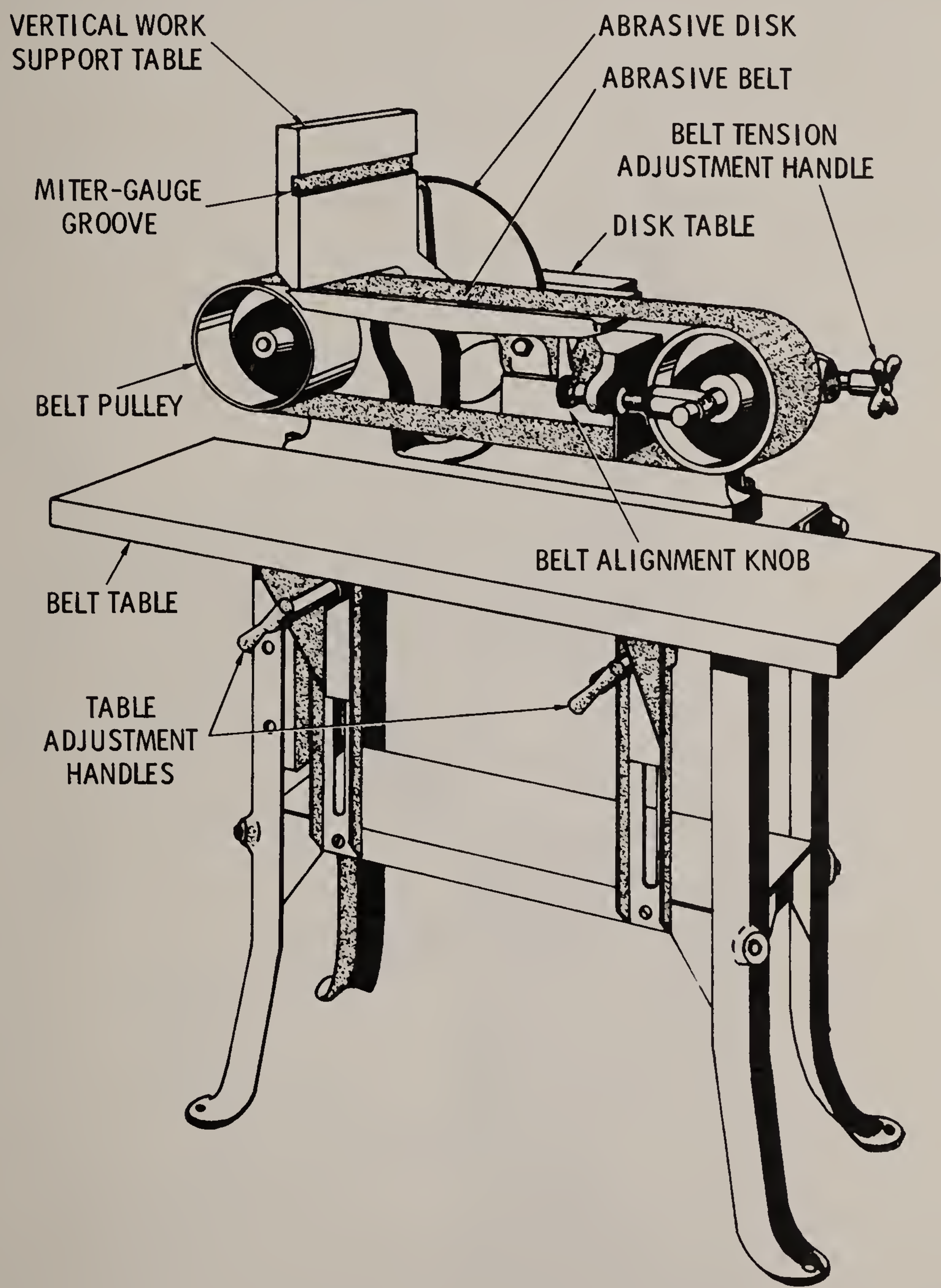
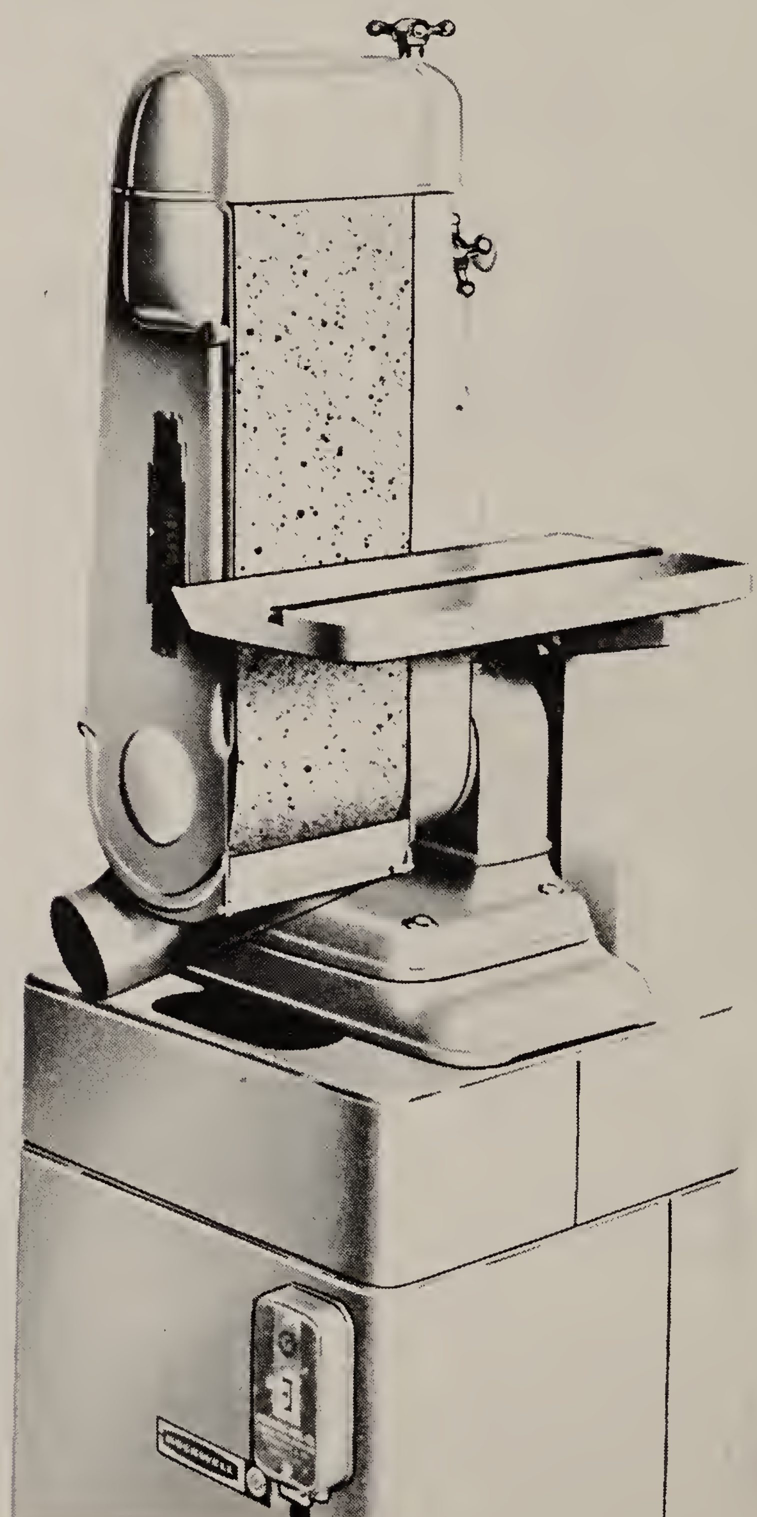


Fig. 1. A belt and disk sander. This type is ideal for the home workshop for fine cabinet and finishing work.

Drum Sander—These sanders are generally large production machines used to sand large items such as doors, composition wallboards and other types of flat work. The drum sander is also frequently used to surface the gluing faces of panel frames after assembly of the frames on jigs in order to smooth out any slight differences in the surfaces of adjoining frame members. Pronounced



Courtesy Rockwell Manufacturing Company, Power Tool Division

Fig. 2. A typical belt sander.

differences in surface, however, will require the use of a cutting tool and should be avoided, as they are indicative either of faulty jointing of the members or of careless assembly.

The drum sander is built on the principle of a planer but, in place of the cutterheads, has one or more rotating sanding drums. Certain types of drum sanders are designed to finish both surfaces simultaneously and are equipped with sanding drums above and below the bed. The sanding drums consist of steel cylinders covered with a resilient material such as rubber or felt. These sanders are not often found in home workshops.

The home workshop may often contain a sanding drum as an accessory item to be used in the drill press, radial-arm saw or lathe. It will have a shaft that can be held in a chuck.

Belt Sander—The belt sander, like the drum sander, is more adapted to smoothing planed surfaces of solid stock and plywood.

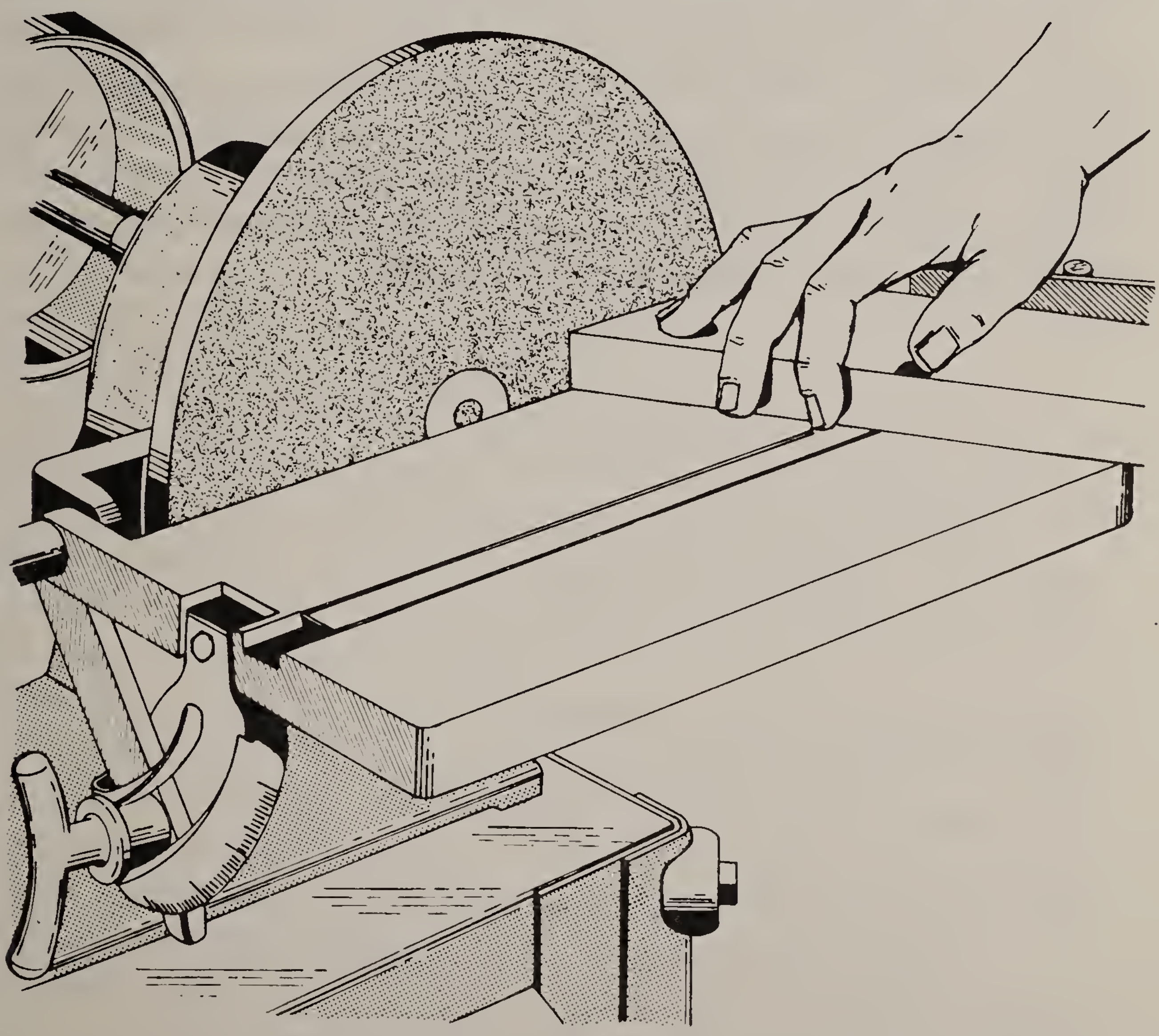


Fig. 3. A disk sander being used to sand the end grain of a piece of wood.

The Sander

Principally, the belt sander consists of two or more pulleys supporting an endless sanding belt, the pulleys being mounted on a cast-iron frame. Between the columns is a table which has a sidewise movement at right angles to the belt. Either the table or the pulleys can be adjusted to the proper height. For ordinary sanding, belts about six inches wide are generally most practical. Paper belts are readily manipulated over curved surfaces. For moldings and irregular shapes, flexible, cloth-backed belts can be ripped to whatever width best accommodates the members being sanded. See Fig. 2.

Disk Sander—The disk sander is most often found as an extra item provided with a power tool intended for another use. For instance, some circular saws include a sanding disk on the side of the machine below the saw table. Sanding disks are also available as accessory items for the radial-arm saw, circular saw, or lathe.

The conventional sanding disk is a metal disk to which the abrasive material must be cemented as a sheet or as a powder. The abrasive must be replaced when it is dull and no longer cuts freely. The latest innovation in sanding disks is the tungsten-carbide type. The grains of tungsten carbide are brazed onto the metal backing and are never replaced. See Fig. 3.

CHAPTER 17

The Drill Press

These machines are made in various types as required in combination with other specialty woodworking devices. The most common drill press is the single vertical-spindle type, fed by a hand lever. Essentially, a drill press consists of a vertical spindle having a chuck at one end and telescoping into a splined sleeve which engages a drive pulley. The assembly is arranged to rotate in bearings attached to the frame of the machine. A table usually capable of angular adjustment is placed under or in front of the chuck to hold the work. In operation, the twist drill held in the chuck is forced into the work by hand feed.

The size of a drill press depends upon the size of work to be bored, and is hence figured according to the largest diameter stock which can be held on the table. Thus, for example, if the distance from the center of the table to the column is 10 inches, a 20-inch disk can be bored through its center, and the size of the drill press is therefore 20 inches.

The speed range of a drill press depends upon the size and number of pulleys, as well as the speed of the driving motor or shaft. In a typical machine equipped with a four-step cone pulley, the speed may be varied between 600 and 5,000 revolutions per minute. The speed of a machine used exclusively for metal working ranges between 400 and 2,000 revolutions per minute.

Boring Tools—All cutting tools used for making holes in wood are called *bits*, whereas similar tools used for metal are called *drills*. A distinction is sometimes made in the cutting operation, the term "boring" applying to holes made in wood,

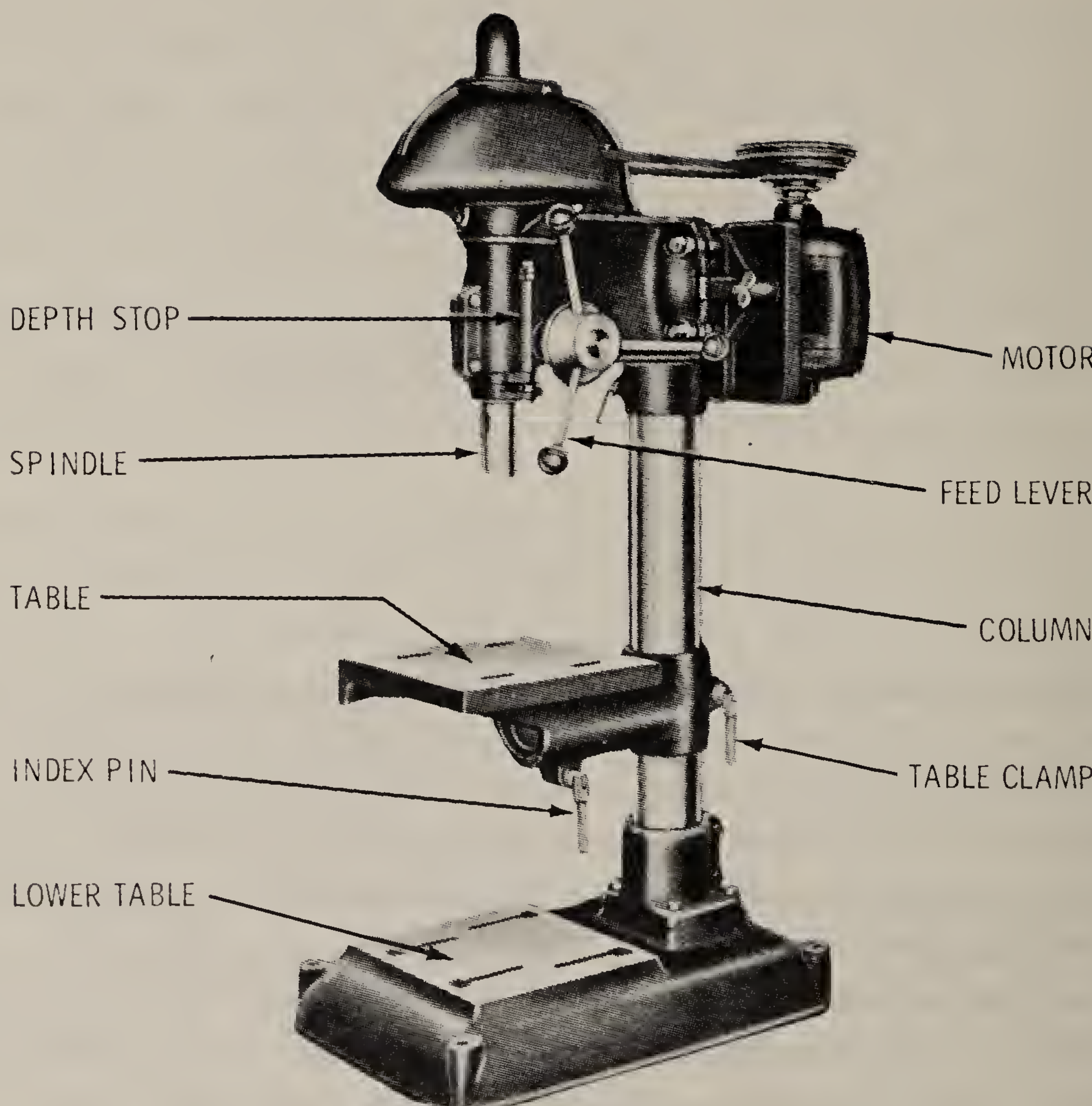


Fig. 1. Typical drill press. With reference to the illustration the four basic elements of the drill press are: base, column, tables and head. The term "head" includes the entire working mechanism of the machine and is attached to the upper part of the column. To facilitate the operation, the upper table can be moved up and down and swung to one side or tilted as the operation may require. The fundamental part of the head is the spindle which revolves in a vertical position, and is supported by ball bearings at each end of a movable sleeve which is termed the quill. The quill and hence the spindle, which it carries, is moved downward by means of a simple rack and pinion gearing, worked by the quill feed lever. When at the completion of the working stroke the feed handle is released, the quill is returned to its normal position by means of a coil spring. Adjustments of the machine may be made by locking the quill and presetting the depth to which the quill can penetrate.

while "drilling" means a similar operation in metal. The most common type of machine-boring bit is the twist drill. Other types are the center and expansive bit, each of which has its particular application in the woodworking shop.

A drill press can be used for many operations other than drilling round holes. With a mortising attachment, the mortise sockets

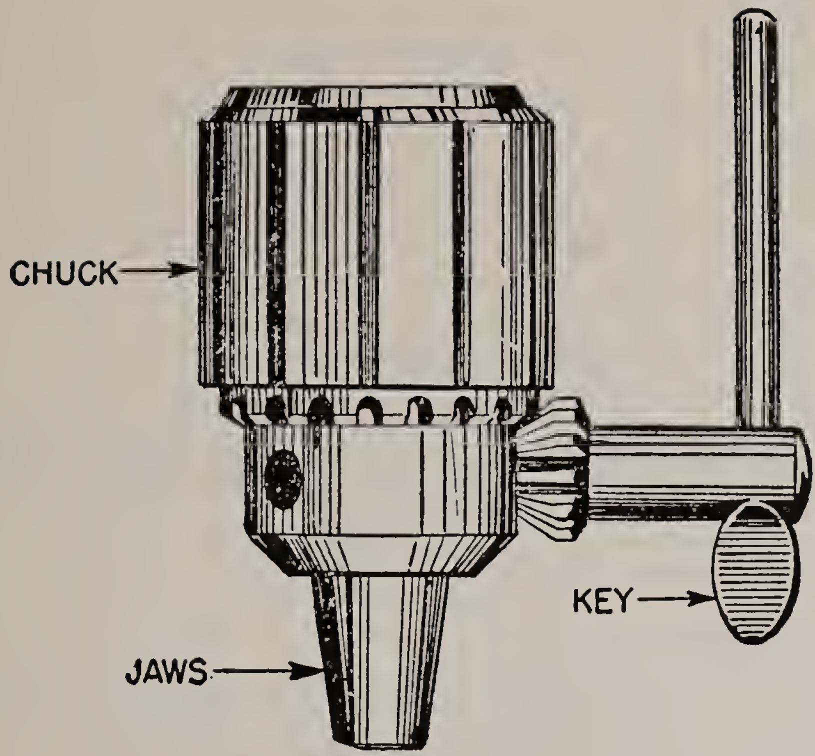


Fig. 2. Typical key-type gear chuck used in drill presses. Principally, the chuck is a clamping device used to connect the twist drill with its driving spindle. Chucks are manufactured in various sizes corresponding to the sizes of twist drills with which they are used. To mount the twist drill in the chuck, place the shank of the twist drill in the chuck as far as possible between the three jaws and tighten the chuck key.

for mortise-and-tenon joints can be made quickly and accurately. A sanding drum can be placed in the chuck for sanding operations. A router bit and the maximum speed convert the drill press into a router. A wire wheel or grinding wheel can be chucked in the drill press. Suitable attachments will also convert the drill press into a shaper or planer.

CHAPTER 18

Portable Woodworking Machines

Many types of woodworking machines have their counterparts in portable equipment, and such equipment finds extensive use particularly in small and medium-sized building projects, as well as in homes and on farms where housing and other conditions prevent installation of more elaborate equipment. Among these are: *circular saws, electric drills, sanders, planers, routers,* etc. Due to the importance of the portable power saw in general carpentry, home construction or alteration and numerous maintenance jobs, a detailed description of this tool is given on the following pages.

Portable Power Saws—These are manufactured in various sizes and are driven by an electric motor with the whole mechanism enclosed within a compact enclosure as illustrated in Fig. 1. These saws are very easy to operate and are made to cut material from two to four inches in thickness, approximately, depending upon the size of the saw blade. In making a cut with a saw of this type proceed as follows: With the switch in Off position, rest the front edge of the saw base flat on the work. Start the saw by pulling backward on the trigger switch and begin the cut, being careful not to jam the saw blade into the work suddenly. Forcing may place unnecessary strain on operating parts and possibly require their premature replacement. For most cutting operations, guiding the saw blade through the work is all that is necessary. If the motor should stall due to a dull blade or unnecessary pressure, do not release the switch at once, but draw back on the saw first, allowing the blade to run free before shutting off the motor. This pre-

Courtesy Skil Corporation

Fig. 1. An electric hand saw of the type used by many carpenters.

caution will reduce burning of contact points and greatly lengthen switch life.

Power Source—Before connecting the cord plug to an electrical outlet, be sure that the voltage of the line is the same as that stamped on the name plate of the tool. When an extension cord is necessary, it should be of wire sufficiently heavy to assure full voltage at the tool with the machine under load. As a safety precaution and particularly in a wet or damp location, the ground wire projecting from the side of the connector should be attached to a suitable ground such as a water pipe, grounded outlet cover or other permanently grounded conductor. The other end of the ground wire should be attached to the tool frame.

Saw Blades—Although saws are most frequently equipped with combination blades for general work, special blades for

rip, crosscut, miter, dado, metal and other types of cutting may generally be obtained from tool manufacturers. Be sure when changing saw blades that the blade teeth are pointing in the direction of rotation of the saw blade.

ELECTRIC DRILLS

The process of drilling holes in metal and boring holes in wood with an electric drill is similar to drilling or boring by hand, except that the power is furnished by an electric motor instead of by the operator. In many operations, it is convenient to mount the drill in a drill stand, and the operator should become accustomed to using the stand as well as the electric drill itself. Drills of this type usually have capacities for drilling holes from 1/16 inch up to one-half inch in diameter.

Fig. 2 shows a cutaway view of a popular type of electric drill. It is equipped with pistol grip or spade handles and has a geared chuck which automatically centers the drill shank in the tool. Many electric drills can be fitted with attachments for driving screws, rotating small grinding wheels, drilling at right angles, etc.

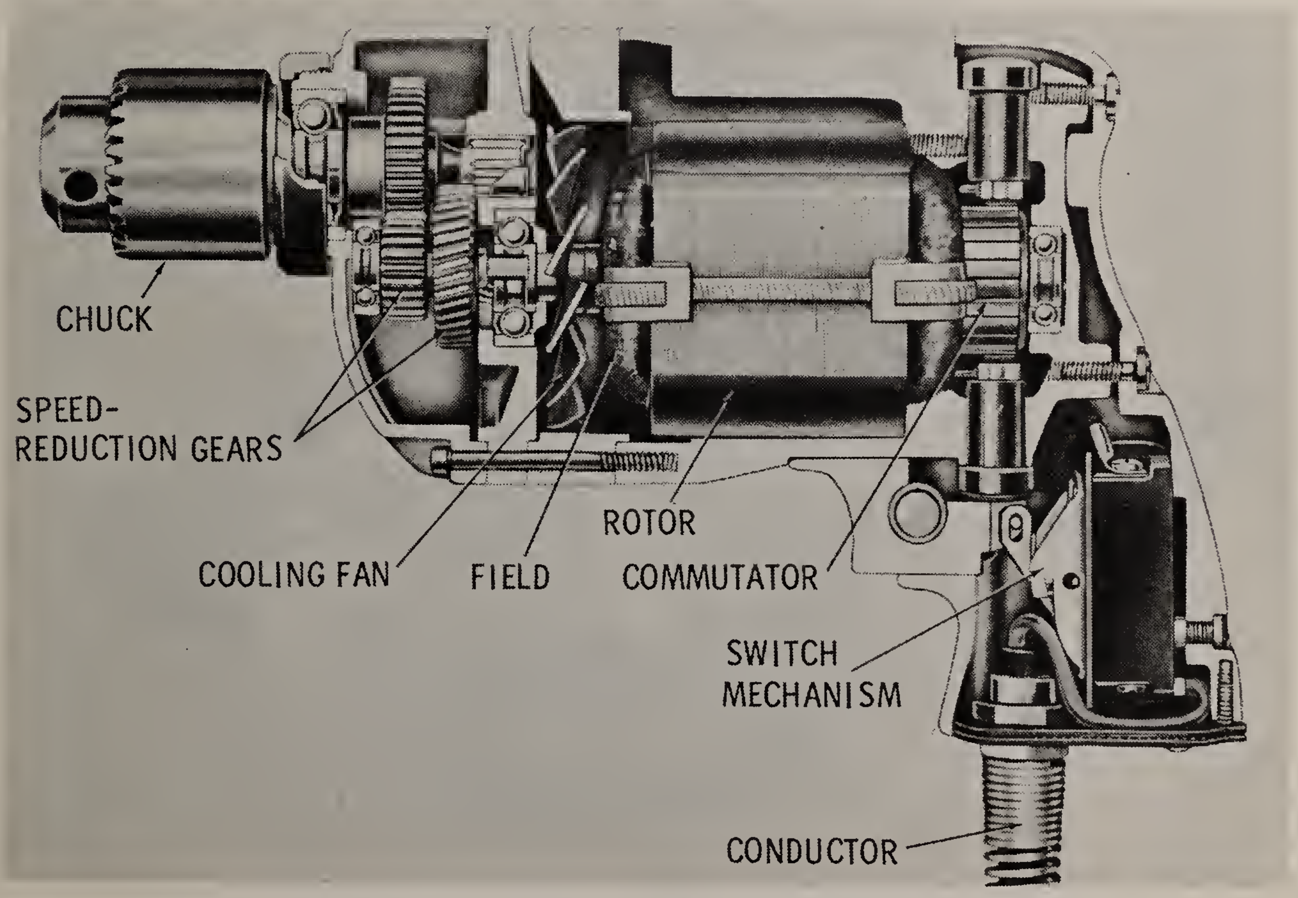


Fig. 2. Cutaway view of typical portable electric drill.

Operations—In drilling holes in metal with an electric drill, the operator must first be sure that the diameter of the hole to be drilled is within the capacity of the tool. Electric drill sizes usually indicate the largest diameter the tool will drill in steel; for example, a ½-inch electric drill is intended to drill holes up to and including ½ inch in diameter and no larger. If used for a ⅝-inch hole, for instance, the work will overload the motor and probably stall the tool.

It is more practical, where possible, to use a drill which has the capacity to drill somewhat larger holes than the work requires. The location of the hole should be carefully marked and started with a center punch, exactly as when drilling by hand; then, with the motor running, insert the point of the drill into the punch mark and start drilling. Care must be taken to hold the electric drill at right angles so the hole will be straight; with the tool held in that manner, exert a light pressure and continue drilling.

If the hole goes entirely through the work, relieve the pressure when the point of the twist drill becomes visible, until the hole is completed. Finally, withdraw the drill and shut off the motor

Fig. 3. Typical drill with assorted accessories.

of the tool. The operator should remember that twist drills do not pull themselves into the work; they must be fed by pressure which must be exerted by the operator in exactly the same manner as if he were drilling entirely by hand. The only effort saved the operator by the electric drill is that of turning.

Operating With Drill Stand—The drill stand aids in accurately locating and maintaining the direction of a hole to be drilled as well as providing the operator with an easy control for feeding the drill into the work. A common type of drill stand is shown in Fig. 4 with an electric drill fitted to it. A lever is provided on such a stand so that the operator can feed the twist drill into the work with either very heavy or with comparatively light pressure.

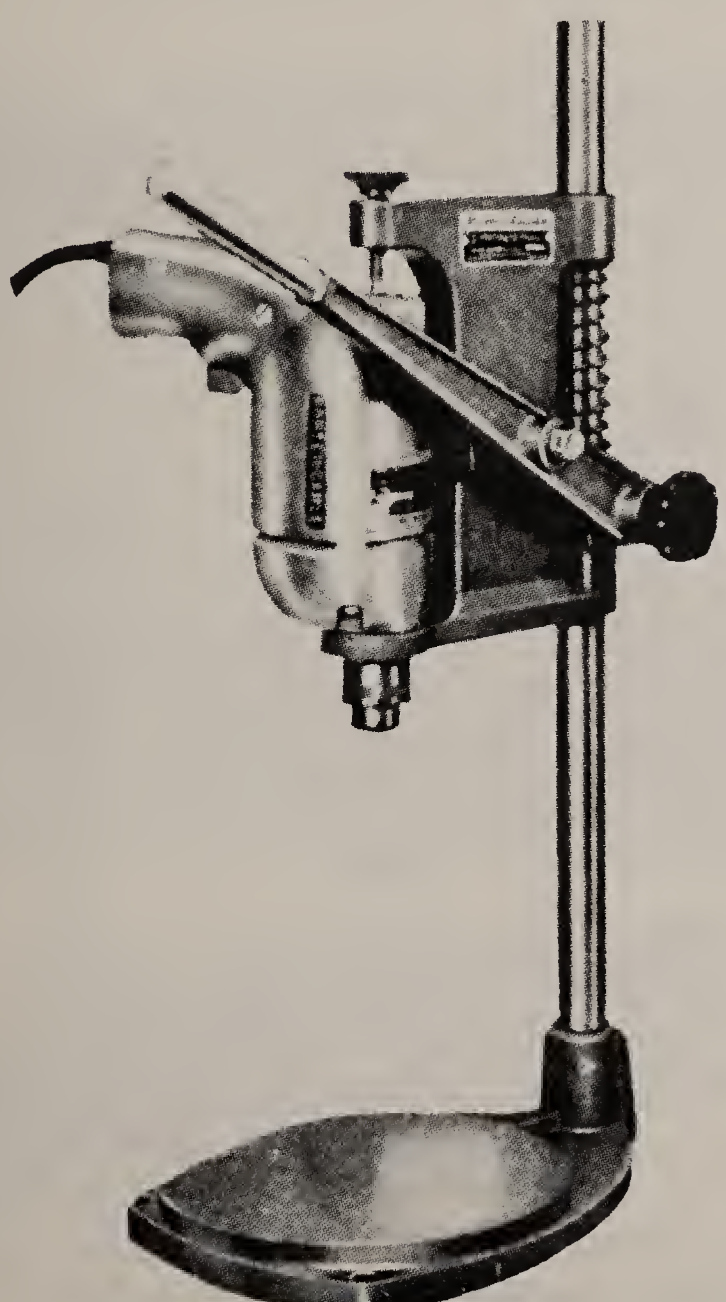


Fig. 4. Method of mounting electric drill in drill stand.

Portable Woodworking Machine

When a drill stand is used, the work is placed on the table provided and the tool brought down by means of the handle; the location of the hole, therefore, must be placed under the twist drill, rather than the twist drill applied to the location, as when drilling by hand. The work should be securely fastened to the table by clamps, and the twist drill fed into it by means of the lever with sufficient pressure to cut, but not enough pressure to cause the twist drill to overheat or the motor to stall.

For accurate work, the drill stand should be used when available, because it is so constructed that the hole will always be drilled accurately at right angles to the work's surface, or at some other angle if the work is clamped to the table accordingly.

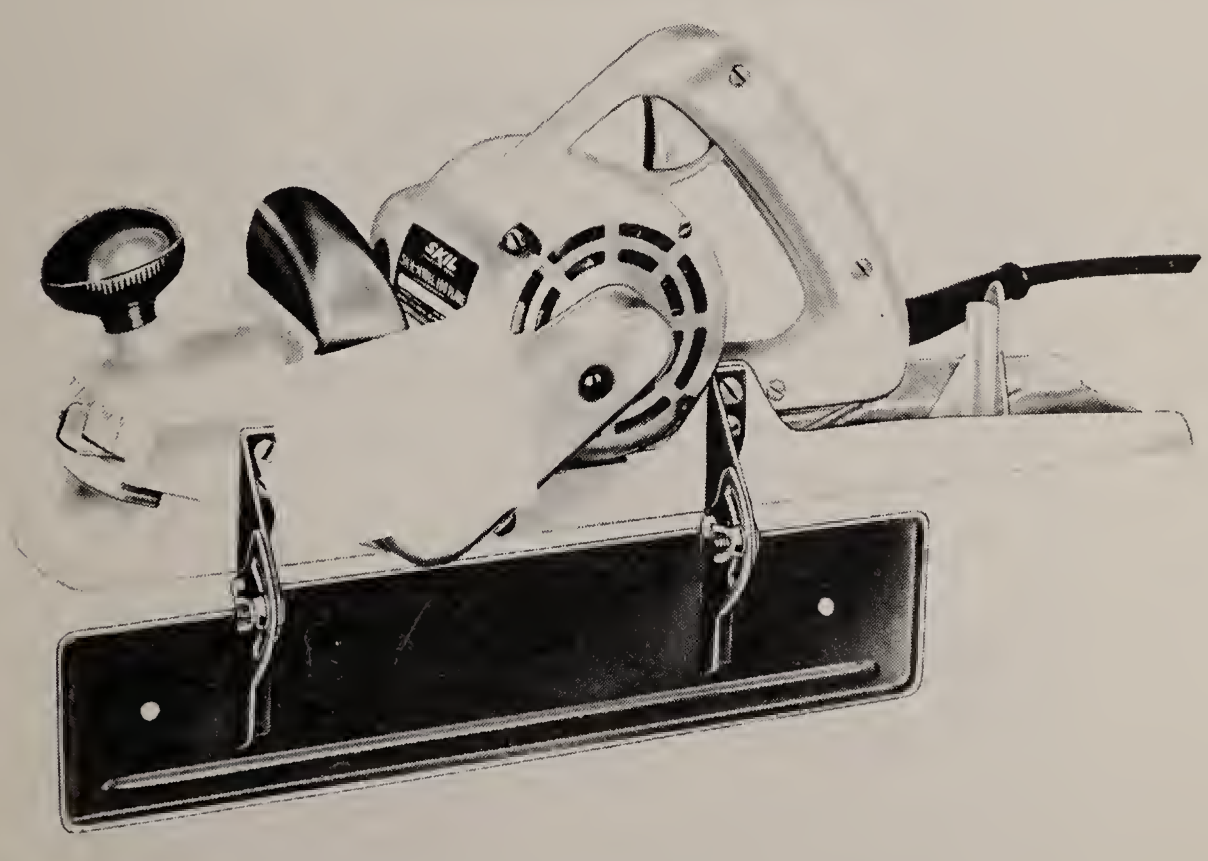
Fig. 5. Portable electrically operated belt sander.

Sanders—A typical portable belt sander is illustrated in Fig. 5. This type of sander lends itself to use in small woodworking shops where only a moderate amount of sanding is required. The portable belt sander is designed for sanding work that cannot be performed on a fixed machine. The belts are normally two inches or more in width. Some portable belt sanders have an attachment which holds the sander to a bench top so that it can serve as a stationary belt sander.

ELECTRIC PLANES

In finish carpentry work, the use of a plane is often necessary. For example, in fitting doors, it is usually necessary to plane one or more edges to obtain the proper clearance between the door and its jamb. A plane is also a necessity when cabinets are built on the job, and for the installation of various other items, such as book shelves.

Electric planes are now available to perform much of the work formerly done with hand tools. An electric plane, such as the one shown in Fig. 6, provides an accurate and rapid means of planing and, in most instances, will result in more precise work with less effort. The model shown is adjustable for depth of cut and has a side fence that can be set to plane any desired angle. When set at 90°, the planed edge will be at a true right angle to the side of the material. The plane in Fig. 6 has a 3-inch cutter which is more than adequate for most work.



Courtesy Skil Corporation

Fig. 6. An electric plane. This model is light-weight and has a 3" cut.

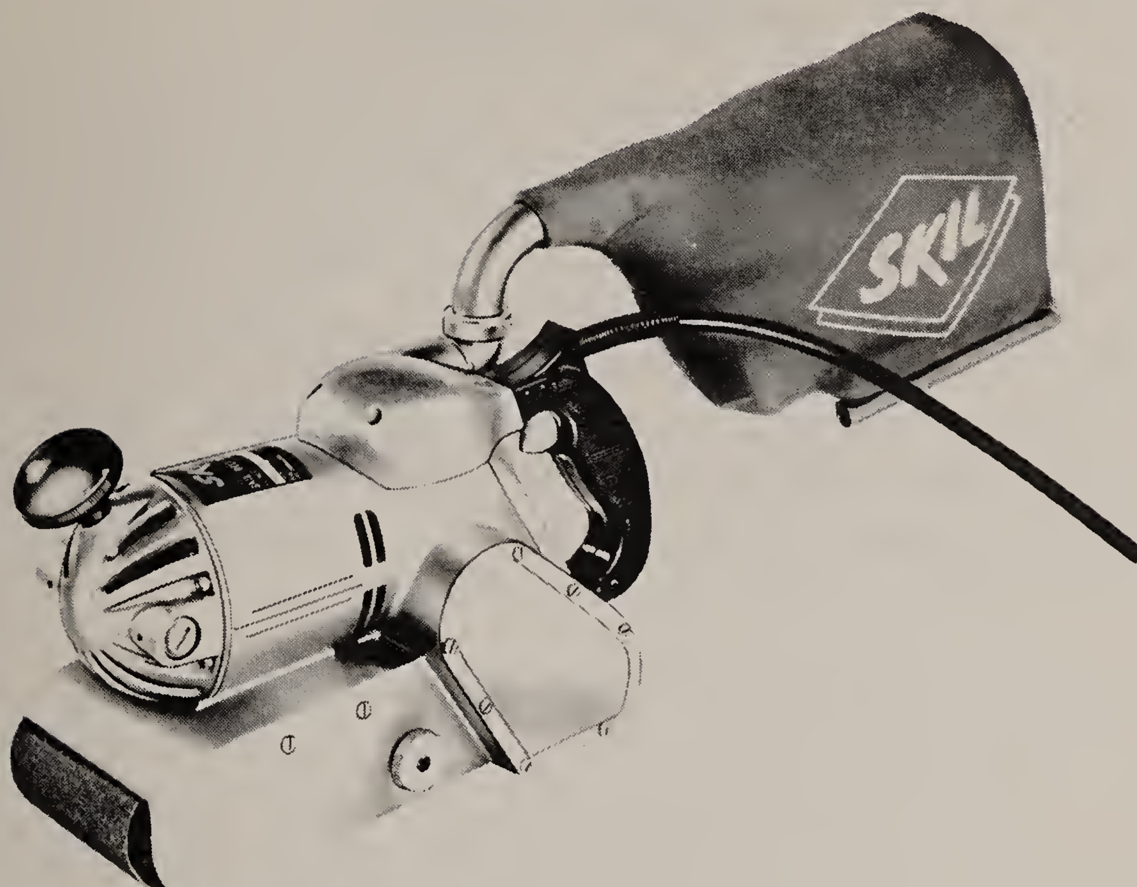
SABER SAWS

Another relatively recent addition to the carpenter's tool collection is the electric saber saw (Fig. 7). The carpenter will find this one of the most versatile tools he owns. Most models are capable of cutting through 2-inch stock with ease and can be used in places impossible to reach with an electric handsaw. Intricate shapes can be cut in plastic, wood, and even metal with this saw by using the proper type of blade. The cut can be adjusted to any desired depth and angle.

A full-range of blades is available for this type of saw, from the standard combination blade for rough cuts in wood, to metal-cutting blades. Even knife-edge blades for cutting leather, fabric, etc., may be purchased. Accessories are also available. These include fences for accurate straight-line cuts, circle-cutting attachments, and offset blade chucks to permit sawing flush with a wall or sawing up to an object.

Courtesy Skil Corporation

Fig. 7. A two-speed heavy-duty jig saw.



Courtesy Skil Corporation

Fig. 8 . A 4½" belt sander with a dust catcher.

Fig. 9. An orbital sander.

PORTABLE SANDERS

A tool that eliminates much of the drudgery from finishing and, at the same time, produces a better finsh is the portable electric sander. There are many types of these handy machines available—the orbital sander, reciprocating sander, and the belt sander. Of the three, the belt sander, such as the one in Fig. 8, provides the most rapid removal of material. The orbital or reciprocating sanders are better suited for final finishing work, however. All grades of grit are available for the belts and sheets used with these machines. The sander shown has a belt which is 4 1/2″ wide. An orbital sander is shown in Fig. 9.

CHAPTER 19

Common Woods and Their Use

The uses and variations in service requirements that a wood must meet are so numerous that it is practically impossible to classify woods in accordance with their suitability for various uses on strictly factual data. There is available, however, the mature judgment of technical experts who for years have been impartially studying and testing the various woods and have observed the service rendered by many woods under varying conditions of service.

Common woods are most often classified according to their degree of hardness or softness, and although no rigid rule exists for this evaluation, it has been found that trees that shed their leaves annually are usually known as *hardwood*, whereas trees of the needle-leaf variety (the evergreens) yield the *softwoods*. The porosity of the grain is another method of classification since the common varieties of wood may be said to have either *open grain* or *close grain*. This second classification is more useful in judging woods used in cabinetmaking than it is for those used in house framing, since the type of finish may be determined largely by the grain.

In some of their properties and uses, hardwoods differ substantially from softwoods. As a class they are heavier, harder, and tougher, and shrink more than softwoods. Hardwoods and softwoods are very similar in stiffness, which means that when reduced to a weight-for-weight basis, the softwoods are much stiffer. In the endwise compressive strength and in bending strength, the two groups are more directly comparable than they are in weight,

toughness, and hardness. The softwoods, as previously noted, are used principally in construction work, whereas hardwoods furnish most of the wood for implements, furniture, and a variety of industrial uses.

A tree is a complex structure of roots, trunk, limbs, and leaves. Only the larger portion of the trunk or bole is used for lumber. This portion is first crosscut into logs. A cross section of a tree trunk (Fig. 1) shows the following well-defined tissue zones in succession from the outside to the center; bark, wood, and pith, a small spot at the center, usually darker in color than the wood.

In most species, wood at the center of the trunk *heartwood* is darker than wood in the outer part *sapwood* and varies from it slightly in physical properties. The relative proportions of heartwood and sapwood in a tree vary with species and environment. Sapwood normally can be seasoned more easily than heartwood. It is more susceptible to fungus and insect attacks, but is more easily impregnated with wood preservatives. There is no difference in strength.

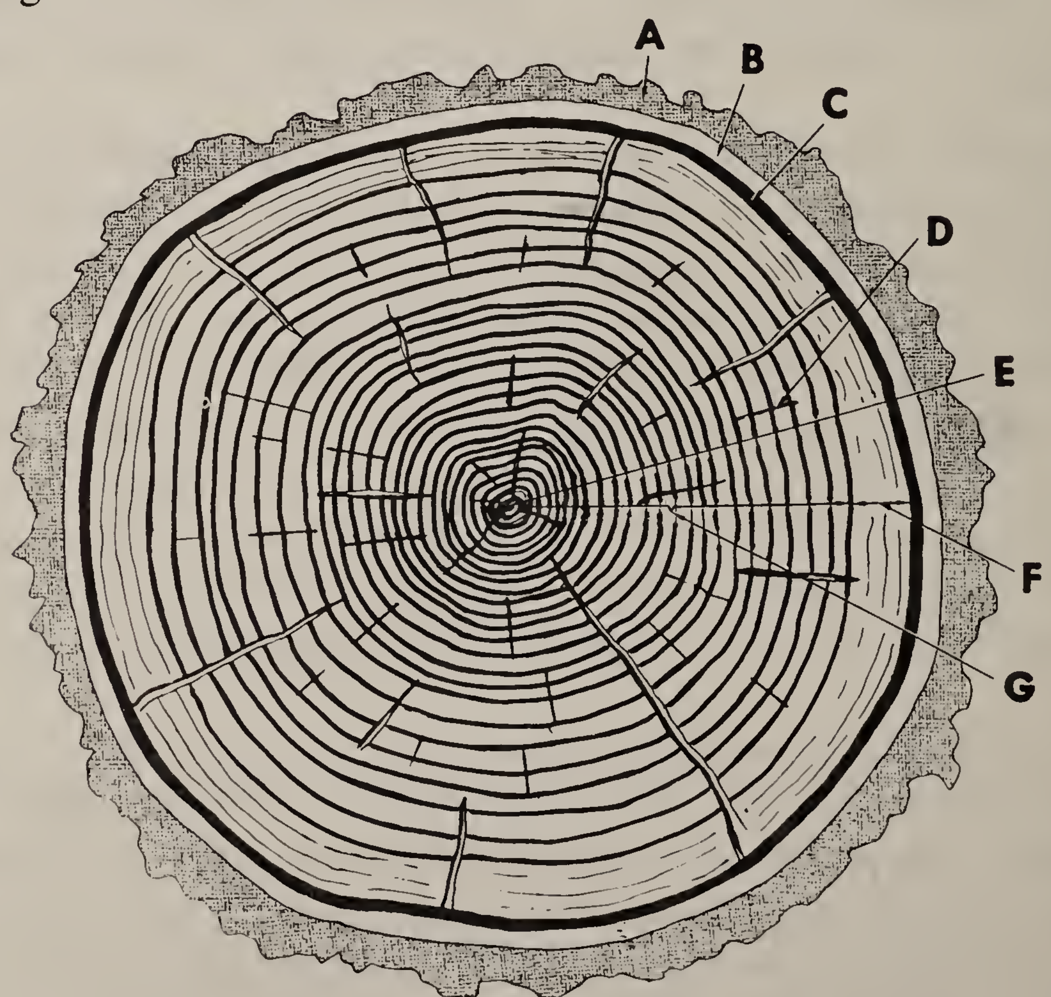


Fig. 1. Cross section of tree trunk—A outer bark, B inner bark, C cambium, D wood rays, E pith, F heartwood, and G sapwood.

The strength of the wood depends on the species, growth rate, specific gravity, and moisture content. Extremely slow growth produces a weaker wood. Softwoods (conifers) also are weakened by extremely rapid growth. Wood with low specific gravity or high moisture content is generally weaker. Defects such as grain deviation caused by spiral growth, knots, and burls, also result in weaker wood.

Structural defects frequently enhance the appearance of wood. Spiral growth results in a winding stripe on turnings. Butt wood shows the assembly of root branches, and crotch wood has a merging or diverging pattern. A burl produces attractive boards showing tissue distortion. The bird's-eye figures resulting from the elliptical arrangement of wood fibers around a series of central spots do not weaken maple wood appreciably. Some quartersawed woods show pronounced whitish flakes where the wood rays are exposed. This forms an interesting pattern especially in oak and sycamore.

Common Wood Defects—Wood, being a product of nature, is subject to many natural defects, some of which cannot be corrected.

Heartshakes are defects of the heartwood found in older trees, especially the hemlock, but they are seldom found in saplings. The heartshake is evidenced by a small round cavity at the center of the wood. This cavity is caused by decay and results in cracks which extend outward to the bark.

Windshake is the separation of the annular rings. This defect is most common in pines. Windshakes sometimes extend several feet up the trunk of a tree.

Starshake is much like heartshake in its effect. The difference between the two is that the starshake has no decay at the center. The cracks over the cross section of the log are wide in the center and narrow down to zero near the bark. The wood along these cracks is solid.

Knots are irregular growths in the body of a tree which interrupt the smooth course of the grain. The fibers of the tree are turned from their normal course and grow around the knot at that point of a tree where a limb is being formed. If the knot is large, cross grains are formed which cause the wood to break easily in and around the knot area.

Checks are splits in the outside portion of a piece of wood and are caused by irregular shrinkage. Checks are formed when the circumference shrinks more than the interior section of the wood, resulting in splits in the exterior section.

Warping is a distortion or twisting of lumber out of its original plane and is caused by evaporation of the moisture in the cells of the wood and subsequent shrinkage of the cell structure. The softwoods have a more even and more uniform structure and tend to dry and shrink more evenly and with less warping than the hardwoods.

Grain deviation is a condition in which the grain does not run parallel to the plane of the board. It may be due to natural or artificial causes. Spiral, wavy, curly, or bird's-eye figures and distortions caused by an injury or knot are natural grain deviations. Artificial deviations result when the plane of the saw cut is not parallel to the outside surface of the log. Grain deviation weakens a board; so, if strength is an important consideration, lumber with grain deviations must not be used, particularly if the grain slope exceeds 1 inch in 15 inches.

Compression wood is frequently found in conifers on the underside of branches and leaning trunks. It is often characterized by an eccentric pattern of annular rings with an excess of opaque summer wood. The higher specific gravity of compression wood does not mean that this is stronger than normal wood. On the contrary, it is weaker and shrinks more in length.

Injuries from handling occur if a log is dropped across a rock, or a falling tree strikes a stump. The fibers are likely to be crushed and much of their tensile strength lost. This defect, known as compression failure, appears on a board as a fine irregular line across the grain.

Molds, stains, and wood rot occur when wood is subject to the destructive action of a large number of fungi. These are microscopic plant growths. Molds attack only the surface of the wood, and do little more damage than a layer of dirt. Since penetration is slight, molds often may be dressed off lumber. Stain fungi discolor wood but do not destroy much of the structure. Wood-rotting fungi break down the wood structure and reduce the wood to dust. Warmth, moisture, and air are necessary for fungus growth.

Insect damage to seasoned or even partially seasoned lumber is usually slight. Certain woods are susceptible to powder-post beetles. If a powdery substance is noticed coming from small holes, these beetles have attacked the wood.

Methods of Cutting—The cutting of trees for lumber and the manufacture of wood products out of the rough logs is a procedure that requires considerable skill and knowledge to result in an economical and serviceable product. The simplest method of cutting a log into lumber is that of straight slicing, sometimes called flat or slash sawing, to a certain predetermined thickness as illus-

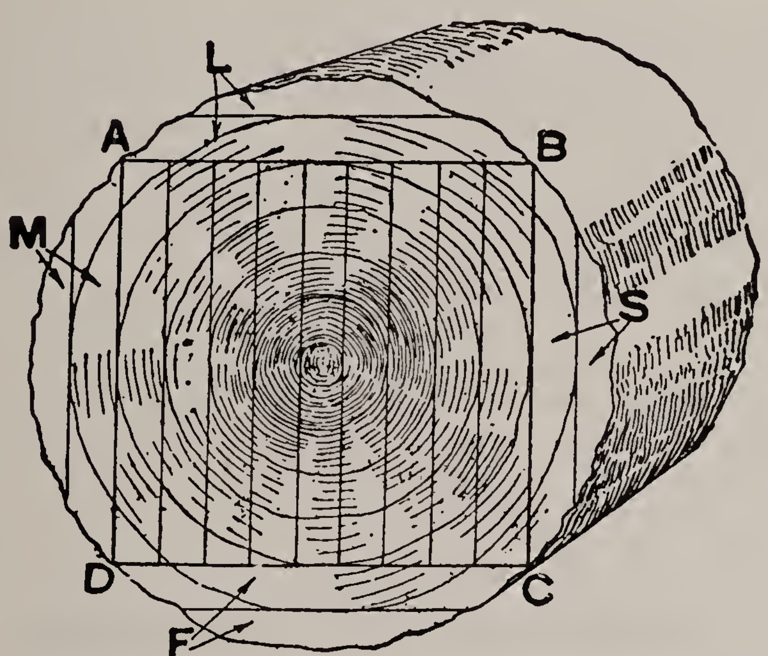


Fig. 2. Flat or slash sawing of lumber. In sawing, the log is first squared by sawing off boards M, S, L, and F, leaving the rectangular section ABCD.

trated in Fig. 2. This is the cheapest method but results in boards which will certainly warp when dry. The better cutting methods are all known as quartersawing in which the log is cut directly into quarters and various sizes of boards are cut from each quarter segment.

The four methods of quartersawing are shown in Fig. 3. Each quadrant, A, B, C, D, of the log illustrates one of the methods. The radical method shown in quadrant A gives the best quality but gives the most waste. The cuts are taken along radii, or in the direction of the medullary rays. This method is the best not only because of the more beautiful surface but also because the wood will hold its shape better than when sawed by other methods. The

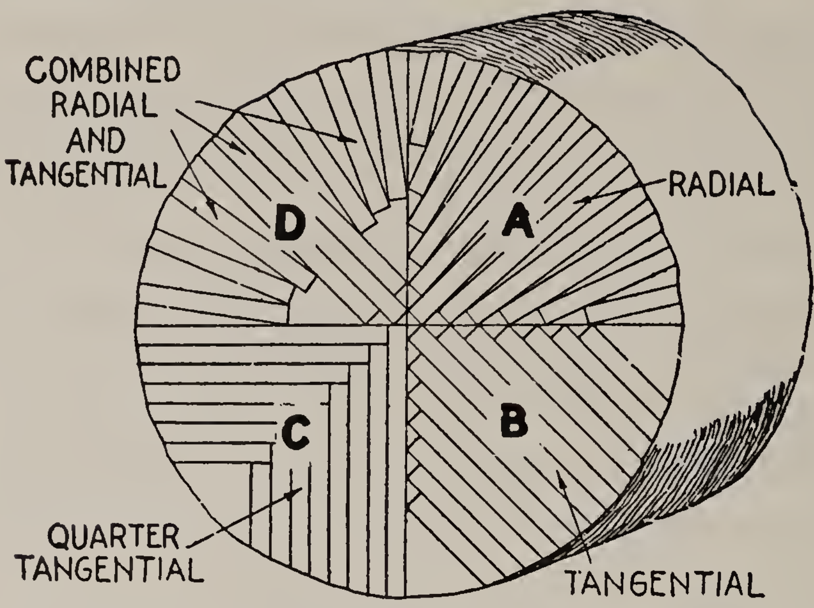


Fig. 3. Various methods of quartersawing. In the sawing method shown, A is termed a radial cut; B is tangential; C is quarter tangential; and D is combined radial and tangential. Quartersawing, or rift sawing, and flat sawing give rise in the lumber trade to the terms "edge grain" and "flat grain" respectively.

reason for this is that a board shrinks most in a direction parallel with the annular rings; hence this shrinkage in a radially sawed board is normal to the surface of the board and warping is held to a minimum.

HOW TO BUY LUMBER

All the miracles of modern synthetics have not ousted wood from its spot as our number-one building material. It is easy to work, plentiful, durable, and versatile. It can be picked for toughness, flexibility, beauty, and hardness or softness. In the form of plywood, it comes in almost any size desired.

The handyman who goes to the lumberyard with a gleam in his eye may come out with a glazed look and a thin wallet. Confusion about grades, dimensions, and prices may needlessly skyrocket a materials bill.

Actually, there is no mystery about lumber grades, sizes, and charges. The man at the lumber stacks does not have time to explain them. In the following pages will be found basic facts and money-saving tips about structural lumber, boards, plywood, millwork, and craft woods. These will help decide what is needed, and when to accept or reject substitute material. If the dealer's assist-

ance is needed, try to go to the yard on a weekday. Saturday is his busy day and he may not have the time to be helpful.

Wood for the Home Carpenter

There are three ways to buy wood for the project being planned. All cost money, but a couple of them can be downright extravagant. One way is to ask the yardman for "some ¾-inch stuff about so big and that long" and hope for the best.

Another way is to tell the dealer what is being built and let him estimate as to construction, finish, and how much money the job is worth. He may play safe and recommend top-grade material, charging accordingly.

The third way is to know how lumber is sold and figure out what is needed, before stepping out of the house. This can save time at the lumberyard, keep the dealer as a friend, and earn cash saving. To buy in this manner, some basic facts about the trade are needed.

Hardness of Wood

Whether the wood is easy or difficult to dent or to drive a nail into does not decide its type. Some hardwoods are fairly soft, and vice versa. Hardness will vary, too, with the part of the tree from which the piece originated and with its moisture content. There is no sharp dividing line.

Woods are properly classified as hardwood or softwood solely by the two groups of trees from which they originate. Those woods from broad-leaved, deciduous trees (which shed their leaves each year) are hardwoods. Those woods from coniferous trees or evergreens, which have needles or scalelike leaves, are softwoods. Most of the wood in the ordinary local lumberyard belongs in this class.

Moisture Content

If cupboards are being installed in a heated house, the wood should be well seasoned or there will be cracks at the joints. For exterior work it can be less dry, and for framing a house even poorly seasoned lumber can do in a pinch. Such wood is easy to nail, can be straightened if crooked, and will be fairly dried out, if the weather stays good, by the time the house is enclosed.

Green or unseasoned wood may be so wet it spouts water when a nail is driven in. Unseasoned wood sometimes can be purchased so much cheaper that it may pay to stack it for air-drying. It may be put up green in such a way that the opening joints do not show. One way is to nail battens along the joints to one board only, and nail them to the other board only after shrinkage has occurred. The wood is, of course, left unpainted. Remember that wood shrinks least lengthwise, and shrinks most across the grain. In a long board, shrinkage can open a corner joint half an inch.

If it is desired to test wood for moisture content and shrinkage, saw off a piece 1 inch in length and exactly 6 inches across the grain. Weigh it carefully. Heat in the oven at 212°F. for at least four hours. Then measure it or compare it to an undried piece of the same stock. If the moisture content is desired find the difference between wet and dry weight, and divide the difference by the dry weight. As an example: a piece weighing 12 oz. originally and 8 oz. after drying (difference 4 oz.); dividing by 8 gives ½, or 50 percent moisture content.

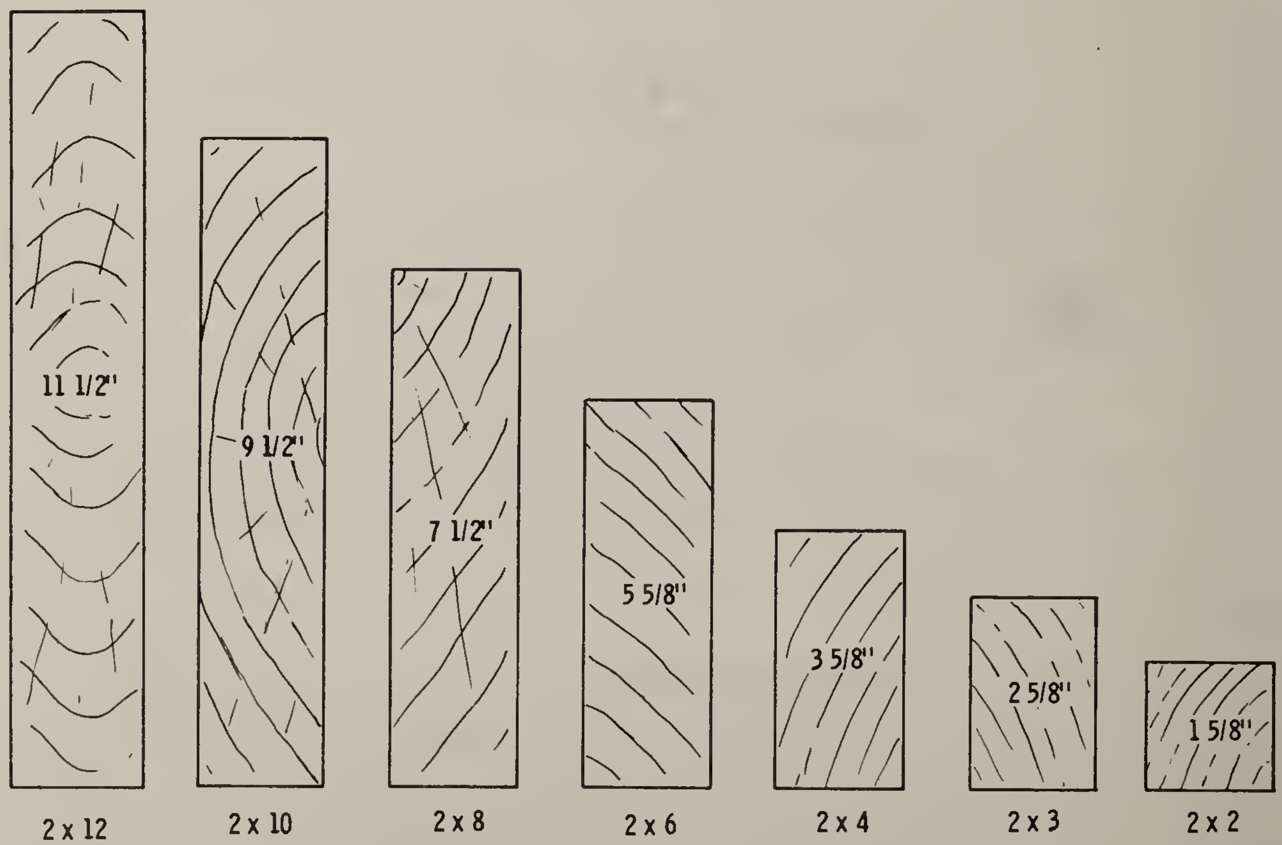


Fig. 4. Actual (finished) width of surface or dressed two-inch boards reduced from nominal-size (rough) boards.

SURFACING LUMBER

Framing lumber may be either kiln- or air-dried and have up to 20 percent moisture. Any wood, with more than 20 percent moisture content is usually considered green lumber. Beware of painting such wet wood; the paint probably will not hold, and will only retard seasoning.

Rough, Surfaced, and Worked Lumber

Lumber comes from the sawmill cut to nominal size (Fig. 4), such as 2 × 4, 2 × 6, 4 × 4, and so forth. In this form it is classified as "rough." After it is run through a planer, it is known as "surfaced," and decreases in size by the amount of wood removed (Fig. 5). A nominal or rough 2 × 4 (Fig. 6) surfaced on four sides (identified as S4S) is reduced to 1⅝ in. × 3⅝ in. in cross section; a nominal or rough 1 × 6 board is reduced to 13/16 in. × 5⅝ in. when dressed. A "five-quarter" board, nominally 1¼ in. thick, reduces to $1\frac{1}{16}$ in. when dressed.

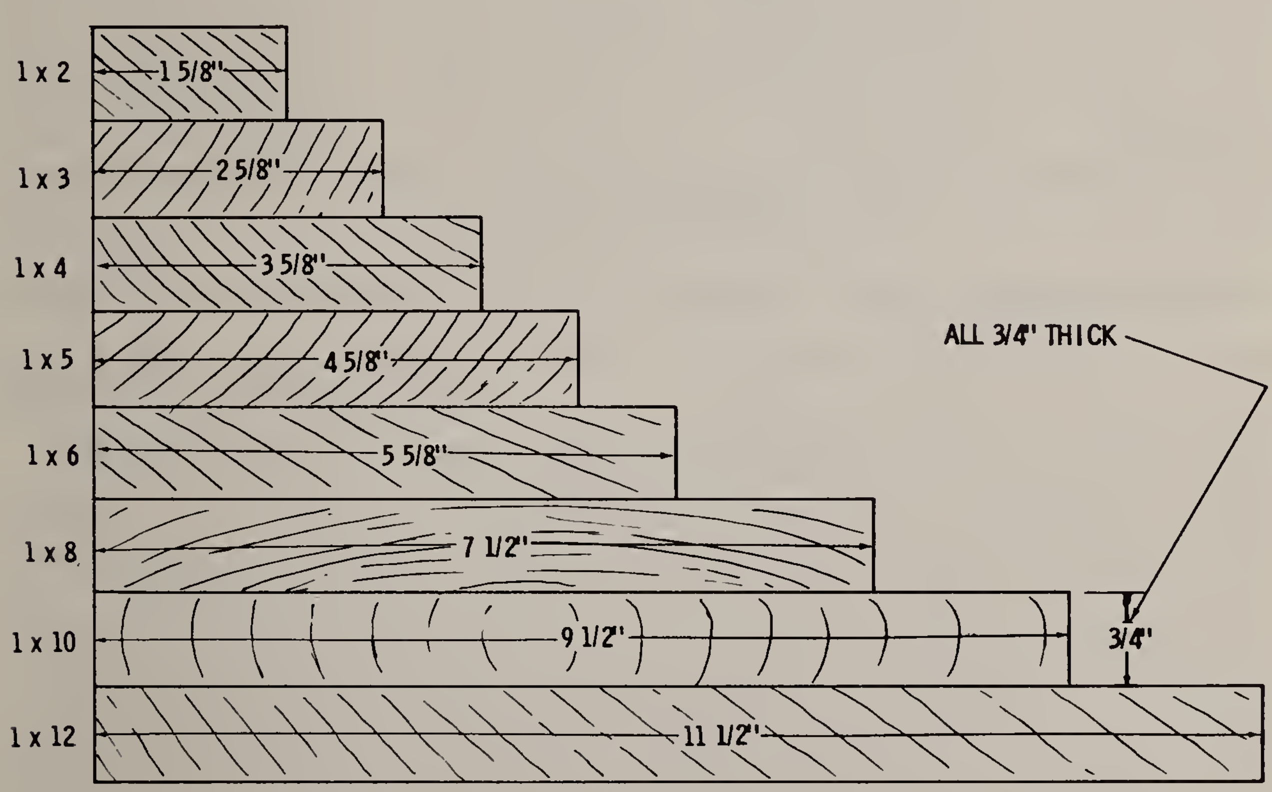


Fig. 5. Actual (finished) thickness and width of one-inch boards reduced from nominal-size (rough) boards.

Some lumber can be purchased surfaced two sides (S2S) or surfaced one side and one edge (S1S1E) and so forth. Rough lumber,

if available, is a good choice for some jobs, although hard on the hands. Rough rafters may be good, for example, while rough studs may cause trouble, because the differences in width would make the walls irregular. Dressed or surfaced lumber, on the other hand, is uniform. Planing straightens the pieces and makes the sides and edges parallel. Uniform width or thickness is important when pieces are to form an even surface for further construction. Studs in a wall, for instance, are placed on edge and therefore should be surfaced across the width and on both edges. The same is true of floor joists. It is wasteful of time to lay odd widths and then dress them to match.

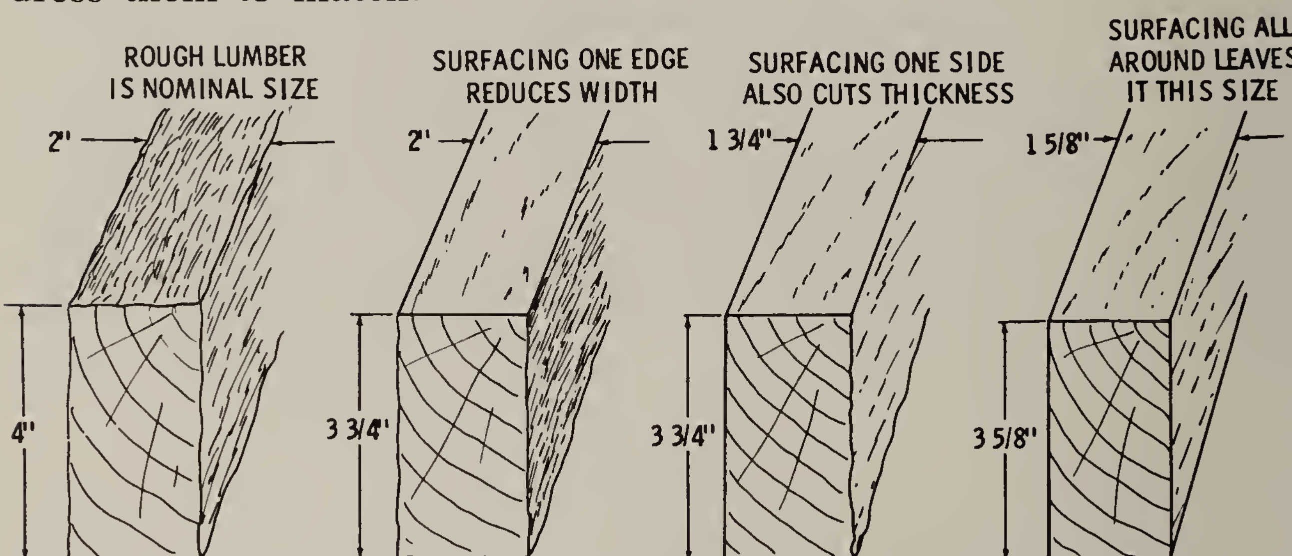


Fig. 6. Reduction in thickness and width of a rough 2 × 4 to a standard-size dressed 2 × 4.

A third classification, "worked" lumber, refers to stock that has been run through a molder, or similar machine, and made into siding, casing, bead or molding.

Surfaced, or sized, lumber is grouped in three categories; yard lumber includes boards and dimension lumber up to 5 in. in thickness. Structural timbers are 5 inches or more. Both groups (Fig. 7) are graded as to quality with the use of the entire piece in mind, therefore a bad defect downgrades the piece. Factory and shop lumber, on the other hand, is meant to be cut up and permits defects between usable sections. This grouping is of special interest to the craftsman.

Grades of Wood

All but the most expensive lumber has defects. Grading regulates the size and number of these. The user should know enough about

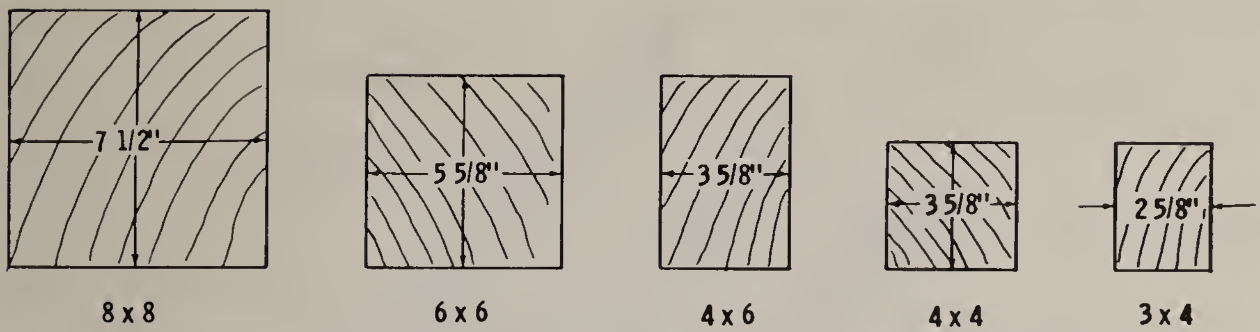


Fig. 7. Reduction of timbers (larger than two-inch boards) from rough or nominal measure to dressed or finished measure.

grading to buy the cheapest lumber suitable for his purposes and also to recognize inferior grades if they are sent by mistake. The safety and durability of a garage or house addition may depend upon this caution. Where building inspectors check on construction, the builder may have to rebuild anything in which less than required grades have been used.

In grading framing lumber (Fig. 8), strength is the chief criterion. For this reason not only the size of the defects and whether they are sound or loose, but also their location is taken into account. A knot near the end of a 2 × 4 impairs its strength less seriously than one in the middle or near the edge. Therefore larger end knots are allowed. Checks (end cracks) may be only one-fourth the thickness of a piece of No. 1 Common; or, if two checks are opposite each other, their total must be no more than one-fourth of the thickness. In No. 2 Common this tolerance goes up to one-third. An accompanying diagram (Fig. 9) shows these grading principles.

Money-Saving Tips

Besides using the lowest serviceable grade for the job in hand, one can sometimes trade time for a cash saving by picking over cull lumber. Much split and otherwise damaged stock is usable. But extra sawing may be required to square off the ends, and only the user can decide whether extra time and labor is profitable.

Milling defects sometimes put lumber on the bargain counter. Hit-and-miss surfacing, in which the knives miss low sections, still leaves boards suitable for sheathing and subfloors, for instance. Some price arithmetic will show whether such lumber is worth buying.

Large beams, like those over wide garage doors, can be bought as boards, but inside defects may be hidden and the pieces hard to

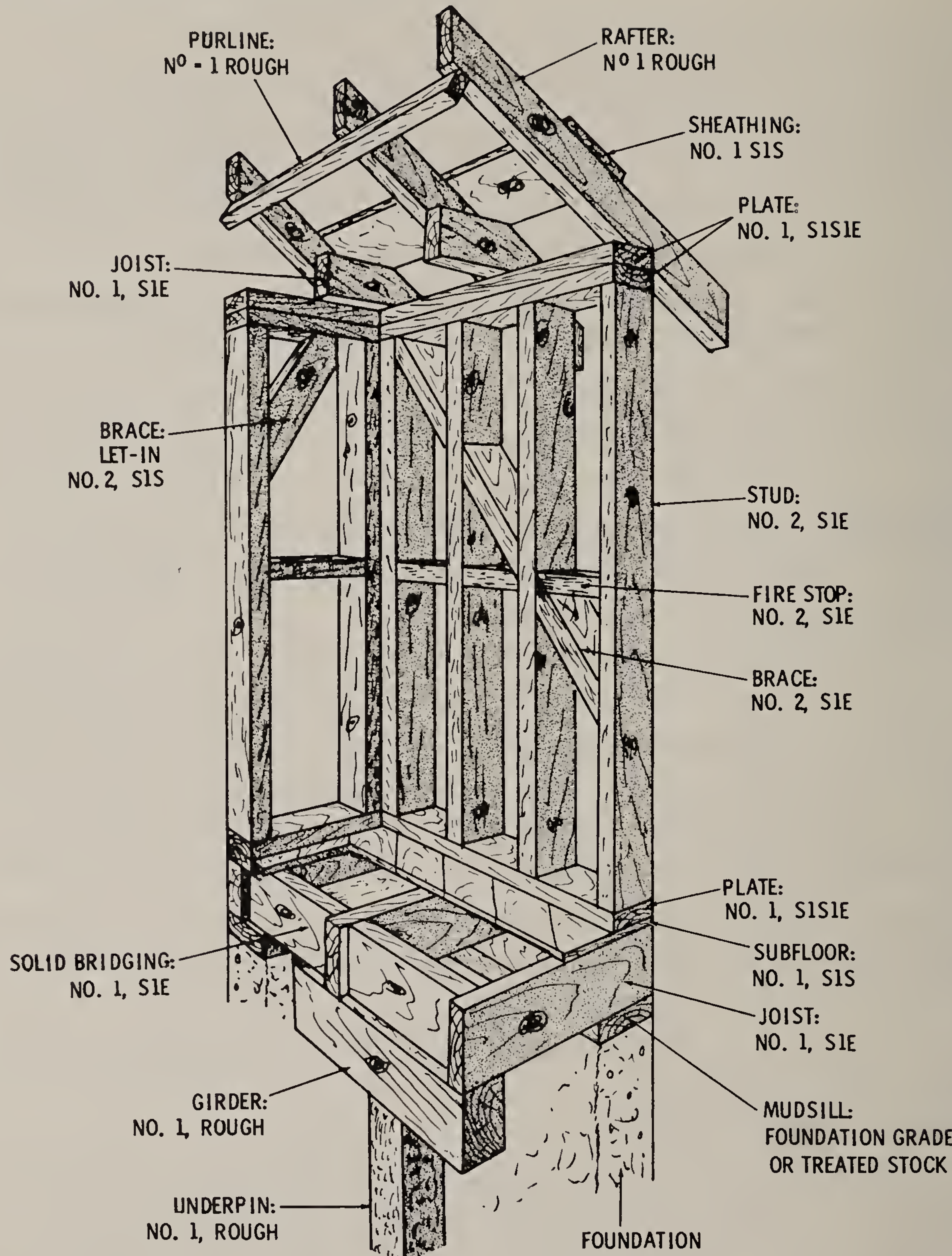


Fig. 8. Typical uses for No. 1 and No. 2 Common grades of framing lumber. Generally, No. 1 grade is used for members in horizontal positions, because they are under greater stress. No. 2 is adequate for vertical members, such as studs.

handle. A good alternative is to spike two pieces of two-inch stock together side to side. Another lumber-saving device, building regulations permitting, is to use 2 × 4 joists over halls and for spans of ten feet or less.

Weaknesses in rafters and joists that show up after they are installed can be corrected by nailing "scabs" of one-inch stock on

each side of the piece. They should extend about two feet each way beyond the defect. Studs bowed edgewise can be straightened by making a saw cut in the concave edge and expanding it with a wedge, afterwards reinforcing the spot with scabs.

It is a good idea to clamp the member against a stiff, straight piece before nailing on the scabs.

Clear stock for porch columns is expensive. A stained or natural finish can be satisfactory even if there are a considerable number of firm knots. For a painted finish one can use even rough or knotty pieces. Chisel back the knots, plug the holes with wood held in with waterproof glue, and fill rough spots with a good surfacing putty or fine sawdust mixed with waterproof glue. Sand well when the glue has set.

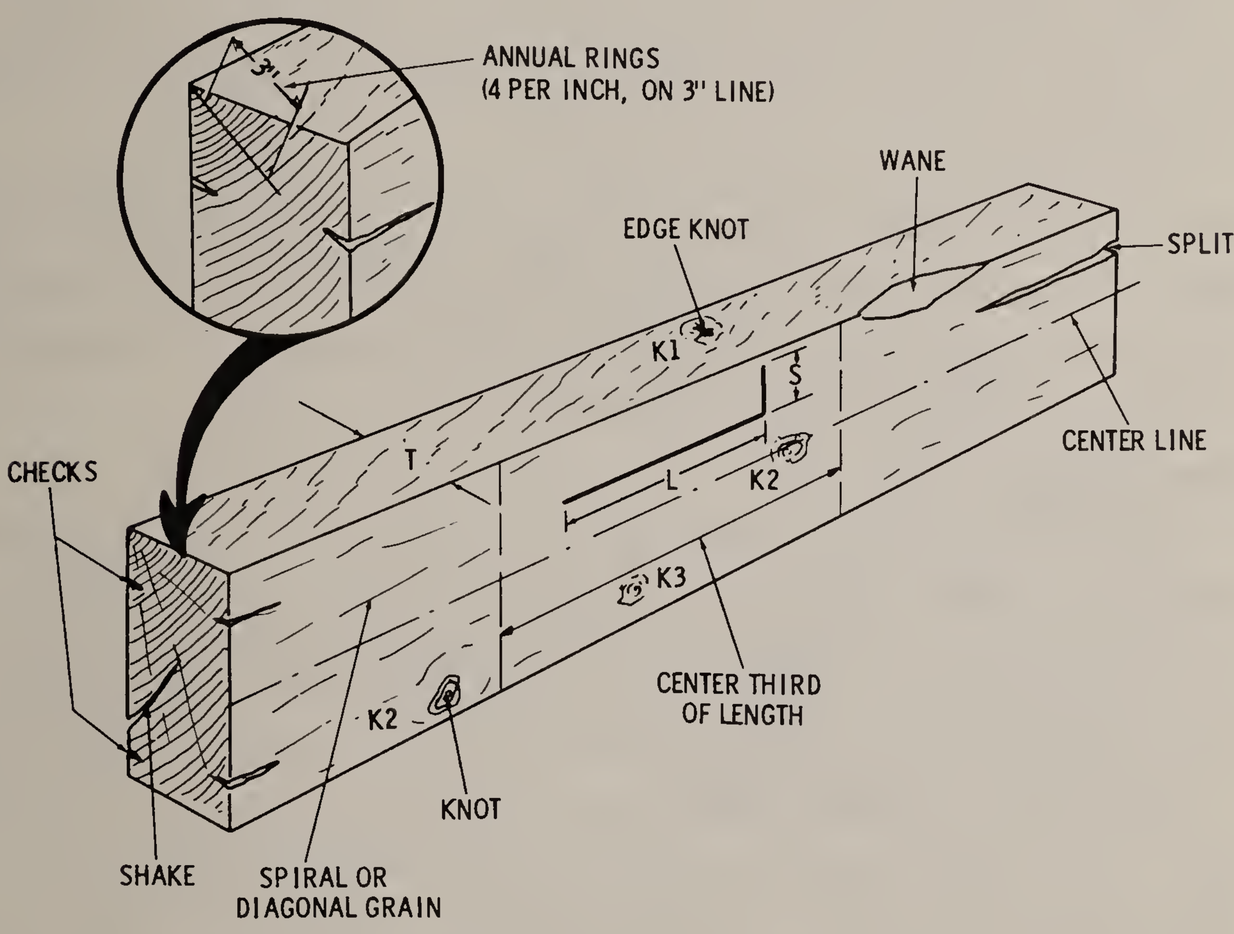


Fig. 9. Grading of framing lumber. The size of permissible defects is a fraction of the width (W) or thickness (T). The location of permissible defects is shown above. For example, in No. 1 Common grade, K3 may equal W/4; that is, face knots near one edge in the center third of the length may be equal in diameter to one-fourth the width of the face. On the center line or at the end (K2), knots may be equal in diameter to one-third the face width. Edge knots (K2) may equal T/3 or one-third the thickness. Spiral or diagonal grain is measured in the center of a board as slope (S) in a given length (L). A slope of 1 inch in 10 inches is permitted for No. 1 Common grade and a slope of 1 inch in 8 inches for No. 2 Common grade.

It is good practice to set door and window jambs before plastering, letting them take the place of plaster grounds. If a person desires the best finish in the least time, he can use kiln-dried lumber, grade B and Better, vertical grain. This grade allows only two or three pitch pockets in a 12-foot length of 8-in. board, or knots or skips on the face, and no cupping.

If one can pick his own jamb stock and is sure of getting straight pieces, he should buy as near finished width as possible. For delivery, sight unseen, it should be wider so that the edges can be jointed straight without making the material too narrow. This also applies to "pulley stile" jambs for double-hung windows already grooved for the parting bead. If this material is bowed edgewise, jointing the edges will still leave the groove curved.

Unless one is certain of getting worked stock that is straight, he should buy plain boards and groove them himself after jointing to width.

Grain appearance is a clue to how well the wood will hold paint. Plain-sawed lumber with wide slashes of hard grain may flake paint off the hard parts. If hard grain appears as threads, it should hold paint well, but the broad hard grain of summer wood makes a board a poor prospect for painting.

Purchasing

By boards the lumberman means stock less than two inches thick and usually over four inches wide (narrow boards may be classified as strips). Pricewise, such stock adds up fast. Therefore it is important to buy sizes (Fig. 10) that can be cut with a minimum of waste, and to get the cheapest grade adequate for the job.

Ordering Lumber—When ordering lumber it should be noted that wide boards usually cost more than narrow boards; that is, one board 1″ × 12″ × 16′ will cost more than two boards 1″ × 6″ × 16′. The standard lengths of lumber are multiples of 2 ft. running from 4 ft. to 24 ft. for boards, fencing, joists, etc. Longer or shorter lengths are special. The standard widths of construction lumber are multiples of 2 inches, and for hardwoods, the standard widths are multiples of 1 inch. All sizes 1 inch or less in thickness are counted as 1 inch thick in figuring cost.

The Board Foot—Lumber is generally sold by the board foot, which is a standard measure 1 inch thick by 12 inches wide by

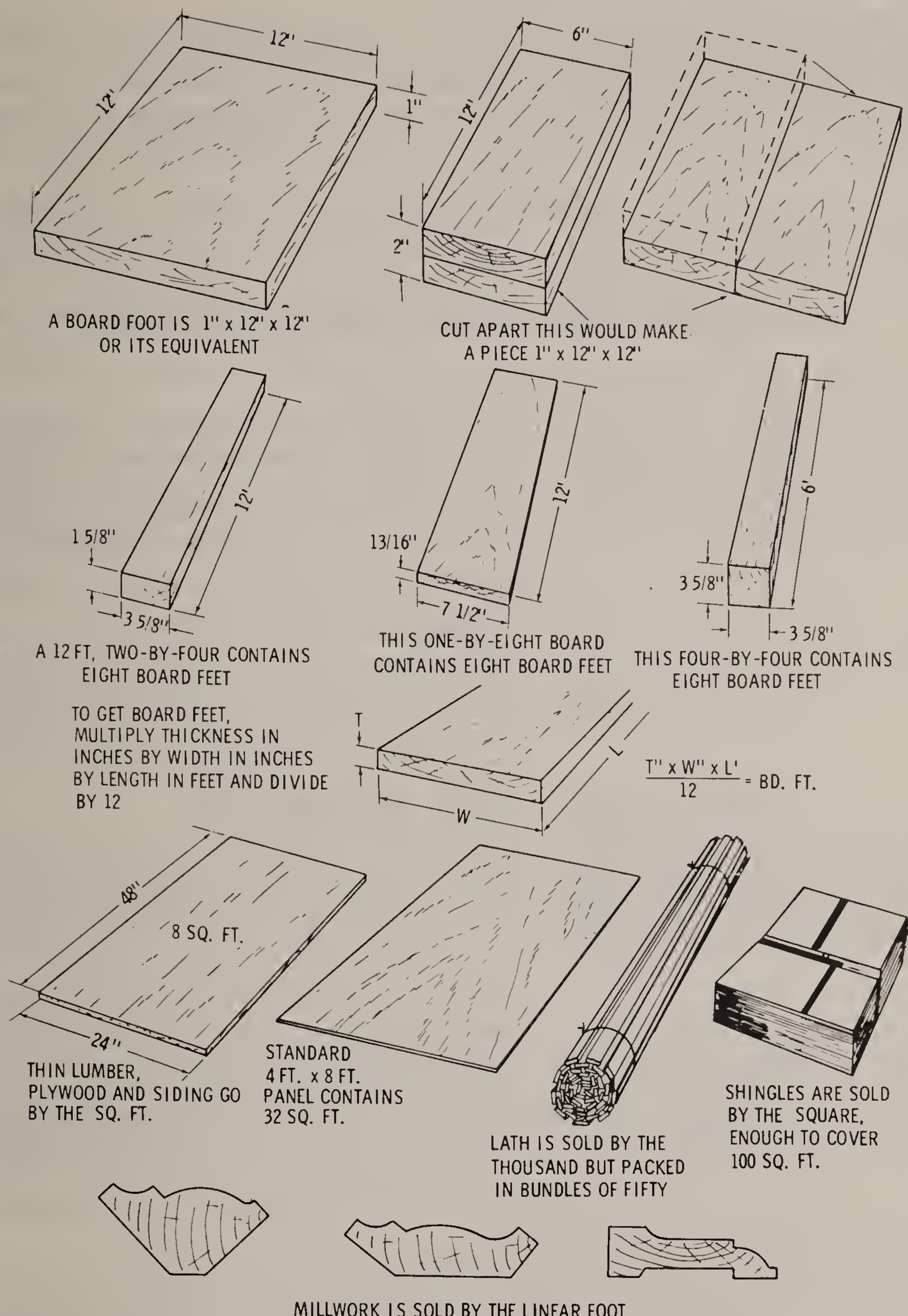


Fig. 10. Standard sizes and method of pricing lumber and materials.

12 inches long. Any size of lumber can be converted to board feet by the following formula:

$$\text{B. F.} = \frac{\text{thickness (inches)} \times \text{width (inches)} \times \text{length (feet)}}{12}$$

To simplify calculations of this sort, lumber dealers use standard tables from which the number of board feet for various sizes and lengths may be obtained directly. Table 1 is a simplified version of such a table and will enable the reader to find the number of board feet contained in lumber of typical cross section and length.

GRADING OF DIMENSION LUMBER

Grading is not an exact science, but depends upon the judgment and experience of the grader. The American Lumber Standards permit a 5-percent below-grade variation between grades. For this reason, and also because two pieces of wood are no more identical than two thumbprints, even photos of typical grades can give only a rough idea of what may be expected. The better face of a board (Fig. 11) governs its grading. Within limits, the back may be poorer.

SHOPPING FOR PLYWOOD

No craftsman should pass up the great advantages of plywood. It is the ideal material for all sorts of projects ranging from outdoor playhouses to furniture.

Plywood can be chosen for weather resistance, beautiful grain, toughness, flexibility, or a combination of these. Often it will save an enormous amount of work by eliminating framing.

The trick of gluing together layers of wood goes back to the ancient Egyptians, who left some nice examples; yet, until recent years, veneered furniture carried a stigma because of a tendency to come unglued or to peel in time.

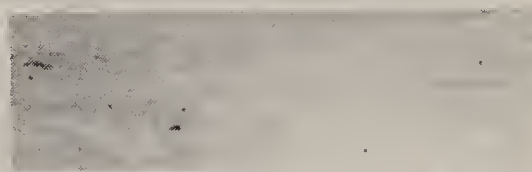
Plastic-resin and other modern adhesives and modern plywood presses have changed this idea. Today's plywood is more resistant to splitting, warping, and shrinking than is natural wood. Pound for pound, plywood is stronger than steel. Plywood is much stronger than boards of the same thickness.

Core Construction

If one looks at plywood edges, two main kinds will be noted. Some plywood has a comparatively thick middle layer of solid

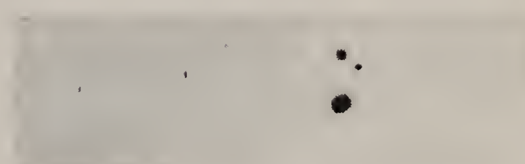
***B and Better** (also called 1 and 2 clear) is top quality, almost free from blemishes, and practically perfect even on the back. It is a luxury unless intended for the finest natural finish.*

***C Select** may have more defects, but all are minor ones such as small tight knots and small to medium pitch pockets. It will take a nice natural finish and is a fair substitute for B and Better.*



***D Select** is the lowest grade of finish lumber, with medium or loose knots and other faults. The back may have more serious ones. Face defects can usually all be hidden by paint.*

***No. 1 Common** may have many small, smooth knots, all sound, none larger than about 2 inches, and rarely on the edges. Surfacing around knots is smooth. Paint hides most but not all its defects.*



***No. 2 Common,** an all-around utility grade, has the same defects as No. 1 to a greater degree. Knots may be up to 3½ inches, though the average is much less. Even paint cannot hide all its faults.*

***No. 3 Common** allows bigger, coarser knots, loose knots and knotholes, as well as some shake splits and pitch. Often a single large flaw will downgrade a No. 2 board to No. 3.*

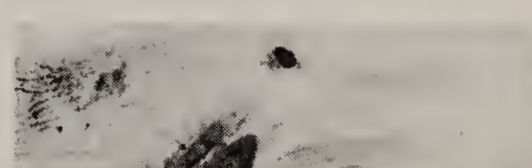


Fig. 11. The six common grades of pine boards.

wood, with a 1/16-in. layer on each side and the very thin face veneer (1/28 in. thick) outside. This is lumber-core plywood. It is ideal for projects like furniture, which call for dowel, spline, or dovetail joints.

Fir, pine, and some hardwood-veneer plywoods may show three to seven layers of similar thickness on the edge, with the grain of adjacent plies at right angles. This is veneer-core plywood. It is

cheapest but not as desirable when edge joints must be made or where edges will be exposed.

Weather Resistance

Plywood is manufactured with different kinds of adhesives for various kinds of service. All three types are clearly identified on the panel edges.

The Face Woods

Veneers for plywood are cut three different ways. For common fir plywood, it is usually rotary cut—sliced off the logs as an apple is peeled. This gives it a wild zigzag grain that is hard to hide or to sand smooth. Other veneers are quarter-sliced or flat-sliced. Each method produces its own characteristic grain. By the last two methods, slices can be pieced together for matched-grain effects to produce an attractive wood surface.

Fir plywood, the most economical, comes in a number of grades differing in surface quality and price. It is the best buy for general utility and for projects in which grain appearance does not matter and comes in thicknesses from ¼ inch to ¾ inch. The standard panel is 4 ft. by 8 ft. but many lumberyards have a stockpile of smaller random sizes.

Ponderosa-pine plywood is widely used for interior paneling and for cabinetmaking and furniture making. Its clear white color makes it ideal for natural or stain finishes. It can also be purchased prefinished.

Hardwood-veneer plywood is available in over 30 different woods. The veneers are variously cut to obtain the most beautiful grain possible, and panels with matching grain can be had. Face woods include birch, walnut, butternut, cherry, elm, gum, mahogany, oak, teak, and many others.

In addition to plain panels, some hardwood-veneer plywoods come in checkerboard panels, in prefinished, and edge-grooved wall panels, and in random-grooved panels.

Plywood Grades

All fir-plywood panels are clearly edge-marked with their type and grade. By careful buying one can stretch his shopping dollar.

Why cut a back for a cabinet from the best grade at 20 cents per square foot if 12-cent wallboard grade will do for the hidden portion of the cabinet.

The quality of the two faces of a panel determines its grade. A "good" face consists of a single sheet of smooth, clear veneer. A "sound" face may consist of two pieces of veneer per panel, perfectly joined but with small imperfections, such as patches, stains, or sapwood. A "utility" face may have knots, pitch pockets, knotholes, and splits (up to 1/16 in. wide) that impair the looks but not the strength of the panel.

Obviously the best grade has two good sides (designated as G2S). This grade can be used when both sides will show and are to have a finish-revealing grain. When only one side will show, a "good-one side" panel (G1S) will save about five cents per square foot. The other side is sound.

For projects that are going to be painted, the sound-two-sides (S2S) grade or even (when only one side will show in the finished job) sound-one-side (S1S) will do. Wallboard grade (WB) has a sound face and utility back. Sheathing (SH) has two utility faces and comes unsanded, in 5/16 in. to 5/8 in. thickness. A special grade for concrete forms, made with highly water-resistant glue, can be used repeatedly. The edges of this ¾-inch panel are sealed with paint, and the faces are oiled.

Another marking system designates faces as A, B, C, and D. Therefore an A-A panel would have two good faces, a panel marked A-C would have a good face and utility back, while sheathing might be marked C-D or D-D.

Special Surfaces

Striking effects are achieved by texturing the surfaces of plywood panels. A series of machine-cut grooves all over the face, for example, produces a novel striated effect. Besides concealing the wild grain of fir, this also disguises butt joints between panels so that no molding is required over them. Striated plywood (Fig. 12) is popular for interior wall paneling, and is cheaper than hardwood veneers. It can be finished natural, stained, or painted.

Striated plywood is also made for siding. This is a three-ply exterior type ⅜ in. thick, precut 15⅞ in. long and 48 in. wide.

It is somewhat cheaper than standard siding, faster to install, and very attractive.

Another surface treatment is produced by wire-brushing (Fig. 13), which cuts down the soft parts of the grain faster than the

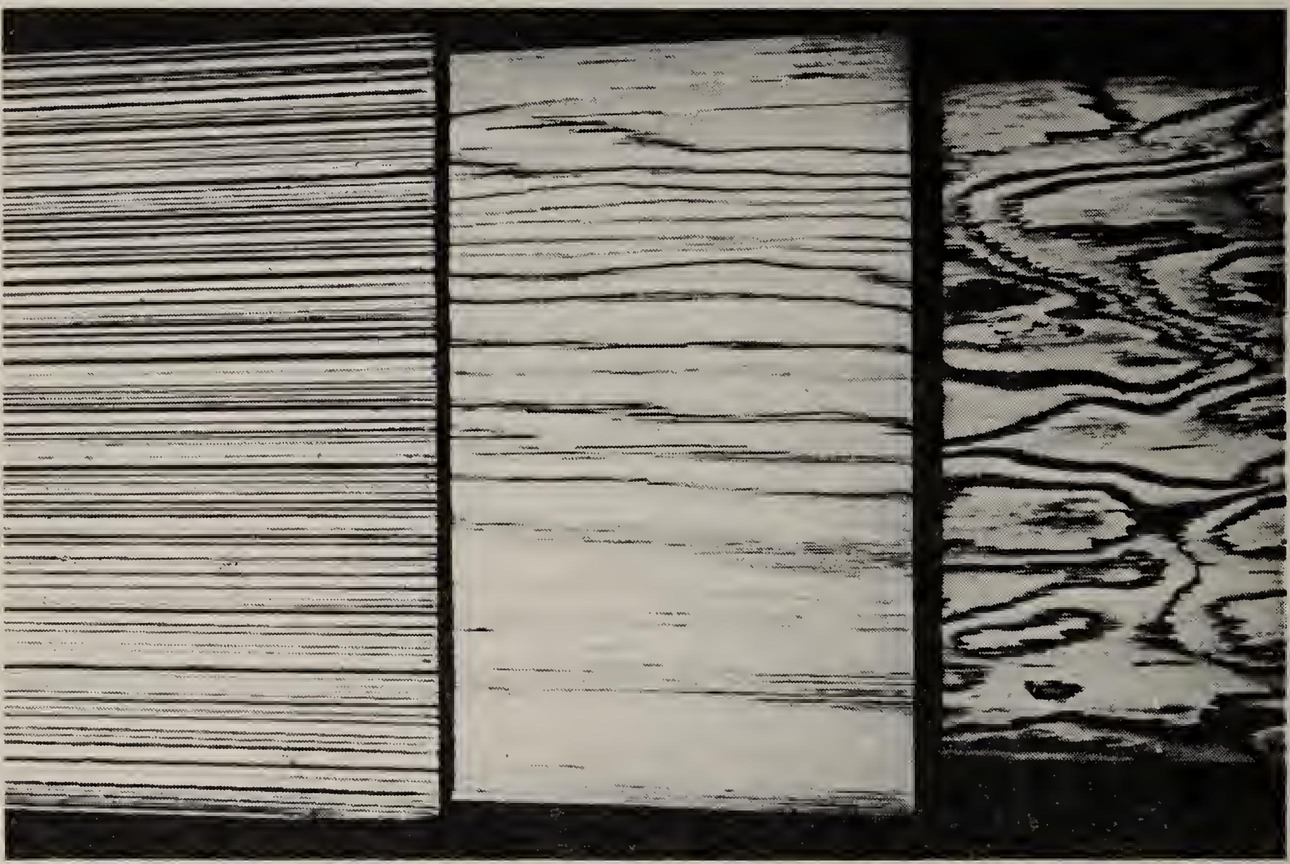


Fig. 12. Special plywood surfaces. Texture treatments either emphasize face grain or disguise it. Weldtex (left) is fir plywood, machine-grooved to produce a striated panel. Malarkey Shadowood (center) is available in both clear and knotty redwood with the soft grain wire-brushed down. Wedgewood (right) has a rotary-cut hemlock face treated to give a sculptured effect.

hard, leaving these in relief. This kind comes in regular 4-ft. by 8-ft. panels and also in panels grooved to simulate planking.

Finishing Plywood

Rotary-cut fir plywood is notable for its wild grain. A good sealer will make finishing easier. Lacquer or wax may be used for a quick, durable, one-treatment finish. Color stains produce striking modern effects. Striated and wire-brushed surfaces respond well to two-color treatment.

MORE PLYWOOD FOR LESS MONEY

If the price for standard "sound-two-sides" or "good-one-side" plywood panels is prohibitive, consider what can be done with

Fig. 13. Wire-brushing emphasizes the grain of the plywood panel. A flexible cable or an electric drill can be used to brush with the grain of the wood.

muscle instead of money. The cheaper grades of fir plywood are not sold for interior finish, but they can be used by doing some extra work.

Occasionally a lumberyard will have a stock of "reject" panels (Fig. 14). These may have excessive splits, open knotholes, or patches. Again they may be almost indistinguishable from better grades. Sometimes they are sanded, sometimes they are not, but they can usually be made usable by a small amount of work.

Even if the lumberyard has no rejects, it certainly carries sheathing grade. This comes in three-ply grades 5/16 in. and 3/8 in. in thickness and in five-ply panels ½ in. and ⅝ in. in thickness. Neither face is sanded, but it costs little more than half the price of the top grade.

LOW-COST WOOD FOR CRAFT WOOD

Woodworking hobbyists waste thousands of dollars each year cutting up expensive lumber into small pieces. Quite often the fellow who turns bowls or lamps, carves plaques, or builds knick-knack shelves will buy clear stock or finish grade—the most ex-

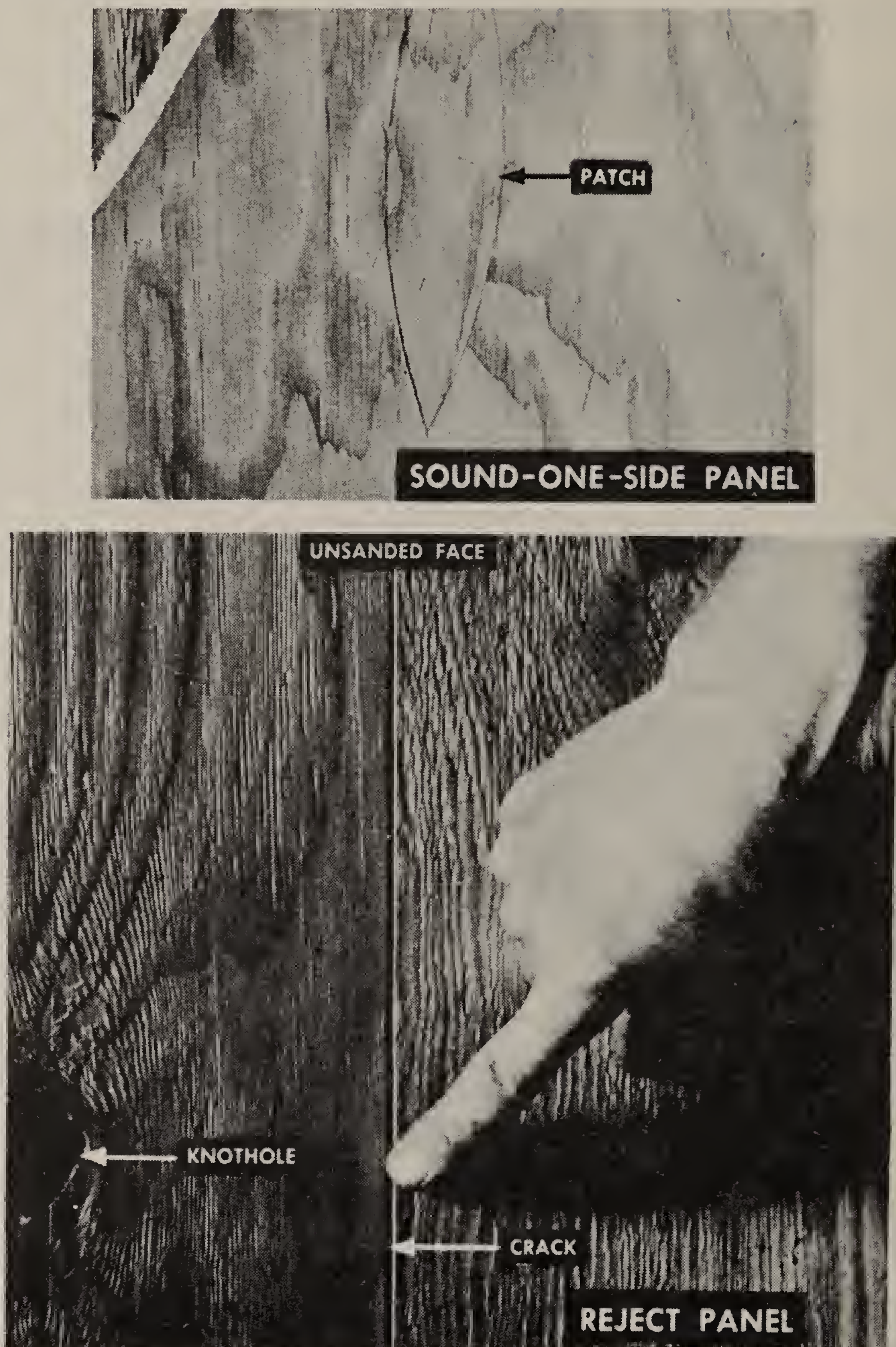


Fig. 14. Difference between a sound panel and a reject panel. Reject panels may have defects, such as the knothole and crack, which can be puttied or plastered for painting. Note the patch in the sound panel.

pensive wood he can buy. Yet he could get wood just as good for his purpose at about half the price.

Shop Grade

The secret of saving money is to buy factory- and shop-grade lumber. If the nearest lumberyard does not carry this, it will pay

to find one that does as it can be an economical source of highly desirable craft woods.

Shop-grade lumber is not pretty at first glance. It has many knots, many of them along the edges, and some holes where loose knots have fallen out. A first reaction may be to wonder how it can be used.

But this material is a gold mine to the craftsman, especially if he has a power saw. By cutting around the defects, he may have a lot of useful pieces just as good as the finished grades that cost so much when purchased as boards. For many projects—lamps, book ends, corner shelves, and candlesticks, only small pieces are needed.

Shop-grade lumber is useful, too, for the man who does week-end carpentering around the house. He will need more ingenuity to use the odd-sized pieces for shelves, racks, vegetable bins, and so forth, but the saving may make it worth while.

Use Those Boxes

Do not overlook the lowly apple box and packing crate as wood sources. The ends are often ¾-in. soft pine, which is suitable for many small projects. Crates are sometimes made of hardwood in the poorer grades, but between the splits and knots short pieces of usable craft wood may be found.

The thin sides of fruit boxes are ideal for such small items as birdhouses, spice shelves, spoon holders, and colonial reproductions.

Sources of Hardwood

Wonderful hardwood can often be found in one's own or in a neighbor's attic. Old pieces of furniture—bed headboards, chests, and especially old extension-table leaves—are good sources.

The only drawback to using such material is the old finish, which usually has to be removed. Do not make the mistake of trying to sand it off with a disk or belt sander—it will clog the abrasive cloth rapidly. Coarse, open-grained sandpaper of the kind used on floor sanders is better. The safest way to strip the wood is with paint remover and a scraper.

Scraps of new hardwood are sometimes obtainable as mill ends. Look for a lumberyard that does millwork. Sometimes stock may be needed of less than standard thickness, which normally is hard to find. The mill may have leftover stock, of ⅜-in. or ½-in. thickness from large milling orders.

Most local lumberyards will carry chiefly the softwoods commonly used for construction work. That means that if one is determined to use hardwoods, he may have to forget about a low-cost job. The lumber dealer may be able to order any special hardwoods wanted, or they can be ordered from one of the mail-order houses specializing in craft woods.

Wood from such sources usually will be perfect, every piece is selected and usable to its full size. Naturally, it also costs more.

IDENTIFICATION OF WOODS

When birch or maple is ordered, from a craft-woods dealer, one usually gets what he had ordered. But there is a trick to it: the dealer keeps each kind in a separate stack. Once they are mixed even the experts could not put them all back correctly.

Fig. 15. Pine. Light in color and weight, most pines range from off-white to light tan, sometimes with an orange cast. Southern pine is brownish yellow.

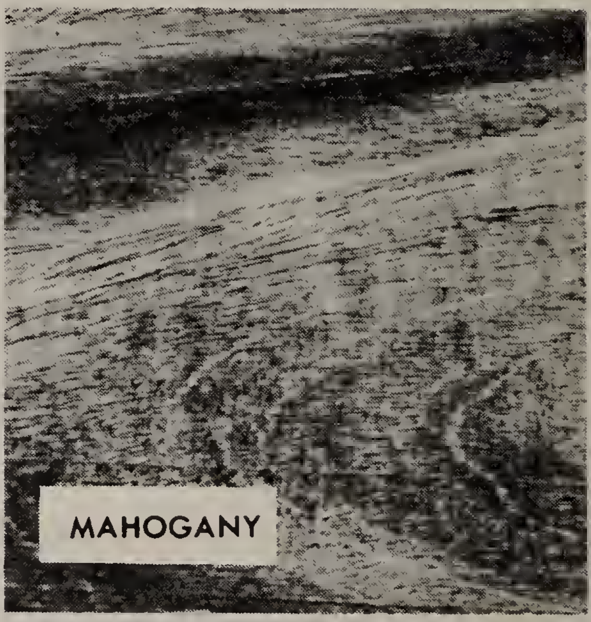


Fig. 16. Mahogany. The color of this wood is similar to finished mahogany furniture. It has open pores, moderate hardness, and is fairly heavy.

Nature never quite duplicates anything and, since wood is a natural product, no two pieces are ever exactly alike. Although

one piece may unmistakably be maple, many pieces of maple might be taken for birch. Furthermore, there are varieties even within a kind of wood—nine, for example, of white oak. So one should not underrate himself if he is not sure of the kind of wood.

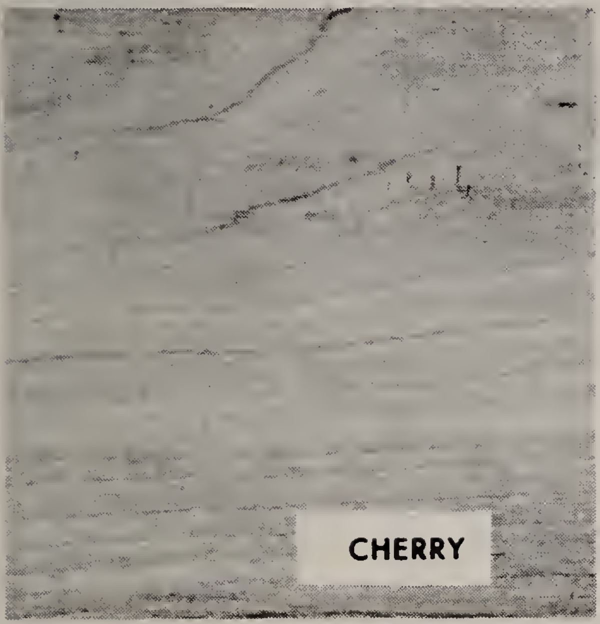


Fig. 17. Cherry. This wood is actually a light reddish-brown color —about as dark as white oak— with perhaps a green cast. Cherry furniture is often deep red in color. It is close-grained, fairly hard and heavy.

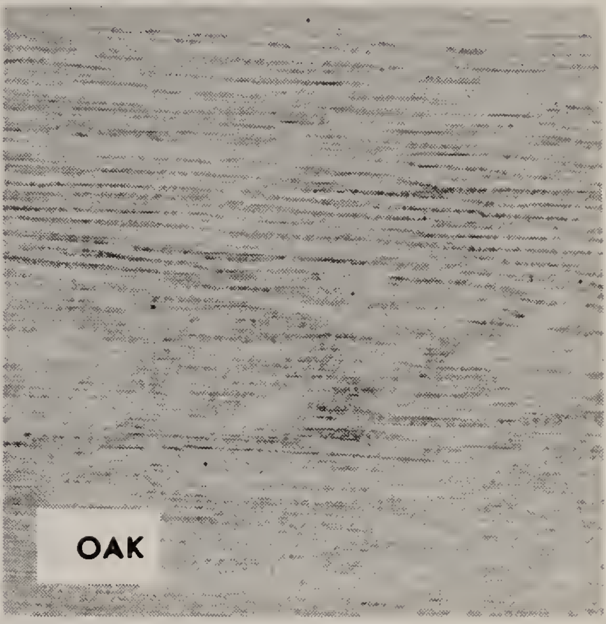


Fig. 18. Oak. White oak ranges from light tan to light brown in color; red oak is reddish or light reddish brown. This wood is extremely hard and heavy.

Fig. 19. Birch. The sapwood is yellowish white and the heartwood is reddish brown in color. It is a close-grained wood.

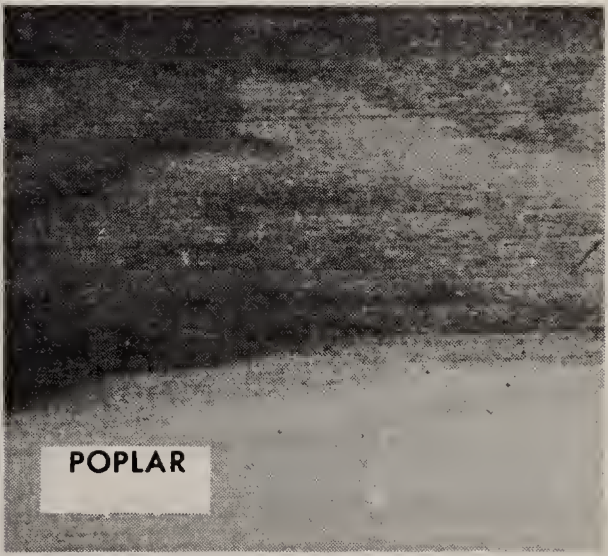


Fig. 20. Poplar. This wood is often called whitewood. The sapwood is almost white, but the heartwood is pale olive to yellow brown in color. It is moderately soft and lightweight.

Fig. 21. Maple. Hard maple is hard and heavy. Its color is light tan, lighter than pine but darker than poplar. It has a very fine texture and grain.

Fig. 22. Walnut. This wood is very dark. It is a chocolate-brown color. The texture is fine and even. The wood has open pores and is moderately dense and hard.

The above photos show typical examples of eight common woods (Fig. 15 to 22), and the captions give clues which help to tell one wood from another. Grain, color, and even hardness may vary widely. If a person keeps a mixed stack, the surest way to tell the kinds of wood apart is to mark each piece the day he receives it.

HOUSE-FRAMING WOODS

The primary requirements for house-framing woods are good bending strength, good nail-holding power, hardness, freedom from pronounced warp, and dryness.

Spruce—The term Eastern spruce includes three species: red, white and black, all having about the same properties. The wood is light in weight, of medium strength, and is easily worked with only a moderate amount of shrinkage. Eastern spruce is used principally for framing and general millwork. It is also used in large quantities for boxes and crates.

Fir—Genuine fir may be distinguished from pine, spruce, or larch by the absence of resin ducts. In hardness and appearance it closely resembles spruce. It is light in weight, rather low in strength, moderately soft, and straight grained. It is easily worked

and neither shrinks nor warps to a great extent. Its main use is in house framing for small and medium-size homes, and it is also used for making boxes and plywood.

Hemlock—Hemlock is reddish brown in color, light in weight, and moderately low in strength. It is rather soft, and it warps and checks badly. It is splintery and splits rather easily, although it holds nails well. It is commonly used for framing, sheathing, roofing and subflooring and for other purposes where a coarse, cheap lumber can be used.

Pine—There are numerous species of pine with varied characteristics. The Southern yellow pine, also known as hard pine, longleaf pine, etc., is well known for its use in heavy construction work. The wood is rather resinous with many ducts, and the grain is straight and coarse. The wood is moderately hard, with extreme hardness in the darker portion of the pronounced annular rings. It is very strong and moderately heavy. It warps only slightly and is quite durable, although it is difficult to work and is likely to split along the annular rings in nailing. It is commonly used in house trim, girders, beams in bridgework, and similar heavy construction projects.

HOUSE-TRIM WOODS

The requirement for wood used in trimming work are: decay resistance, good painting characteristics, easy working qualities, and freedom from warp.

White Pine—This wood is light, soft, straight grained, and easily worked. White pine is unequalled for all purposes requiring a wood that checks and shrinks very little and holds its shape well. It is of medium strength, elasticity and durability. It splits easily but nails well. In color it is light, yellowish brown, often tinged slightly with red. The grain is not noticeable and has no particular beauty. It is commonly used for interior finish and in a great variety of woodworking projects including patternmaking.

Basswood—This wood is a very light brown in color and its grain is straight and close. It is light in weight and comparatively tough. Basswood is very easily worked, holds nails well, and is rather durable although soft in texture. It is generally used in the

construction of less expensive furniture and cabinetwork, and in the manufacture of wooden kitchenware, picture frames, and toys.

Chestnut—The light coarse-grained wood of the chestnut tree

Table 1. Contents of Lumber in Board Feet When Cross-Sectional Area and Length Are Known

[Number of board feet in various sizes for lengths given]

Size of piece (inches)	Length of piece (feet)								
	8	10	12	14	16	18	20	22	24
2 by 4	5⅓	6⅔	8	9⅓	10⅔	12	13⅓	14⅔	16
2 by 6	8	10	12	14	16	18	20	22	24
2 by 8	10⅔	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
2 by 10	13⅓	16⅔	20	23⅓	26⅔	30	33⅓	36⅔	40
2 by 12	16	20	24	28	32	36	40	44	48
2 by 14	18⅔	23⅓	28	32⅔	37⅓	42	46⅔	51⅓	56
2 by 16	21⅓	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
3 by 6	12	15	18	21	24	27	30	33	36
3 by 8	16	20	24	28	32	36	40	44	48
3 by 10	20	25	30	35	40	45	50	55	60
3 by 12	24	30	36	42	48	54	60	66	72
3 by 14	28	35	42	49	56	63	70	77	84
3 by 16	32	40	48	56	64	72	80	88	96
4 by 4	10⅔	13⅓	16	18⅔	21⅓	24	26⅔	29⅓	32
4 by 6	16	20	24	28	32	36	40	44	48
4 by 8	21⅓	26⅔	32	37⅓	42⅔	48	53⅓	58⅔	64
4 by 10	26⅔	33⅓	40	46⅔	53⅓	60	66⅔	73⅓	80
4 by 12	32	40	48	56	64	72	80	88	96
4 by 14	37⅓	46⅔	56	65⅓	74⅔	84	93⅓	102⅔	112
4 by 16	42⅔	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
6 by 6	24	30	36	42	48	54	60	66	72
6 by 8	32	40	48	56	64	72	80	88	96
6 by 10	40	50	60	70	80	90	100	110	120
6 by 12	48	60	72	84	96	108	120	132	144
6 by 14	56	70	84	98	112	126	140	154	168
6 by 16	64	80	96	112	128	144	160	176	192
8 by 8	42⅔	53⅓	64	74⅔	85⅓	96	106⅔	117⅓	128
8 by 10	53⅓	66⅔	80	93⅓	106⅔	120	133⅓	146⅔	160
8 by 12	64	80	96	112	128	144	160	176	192
8 by 14	74⅔	93⅓	112	130⅔	149⅓	168	186⅔	205⅓	224
8 by 16	85⅓	106⅔	128	149⅓	170⅔	192	213⅓	234⅔	256
10 by 10	66⅔	83⅓	100	116⅔	133⅓	150	166⅔	183½	200
10 by 12	80	100	120	140	160	180	200	220	240
10 by 14	93⅓	116⅔	140	163⅓	186⅔	210	233⅓	256⅔	280
10 by 16	106⅔	133⅓	160	186⅔	213⅓	240	266⅔	296⅓	320
12 by 12	96	120	144	168	192	216	240	264	288
12 by 14	112	140	168	196	224	252	280	308	336
12 by 16	128	160	192	224	256	288	320	352	384

is moderately low in weight and strength. Because of its resistance to decay, it is often used for railroad ties, utility poles, and fence posts. It is also used to a certain extent in cabinetwork, interior finish, and in furniture construction.

Oak—In North America, oak lumber is commonly referred to as *white* or *red* oak. Red oak is reddish brown in color with a very coarse grain which makes the wood appear porous. It is heavy, hard, and stiff. It warps and checks badly and is difficult to nail. Red and white oak are frequently used for interior trim, for furniture, for cabinetwork and the like. The color of white oak is light brown. It is capable of receiving a high polish and is extremely attractive when carefully worked.

Maple—Heavy, hard, strong and ideal for general turning operations on the lathe. It is close grained and, when finished properly, makes a fine wood for furniture and decorative work. It is also used in general carpentry work such as for flooring and interior finish.

Birch—The wood of birch is light, reddish brown in color with white sapwood. The grain is closed and fairly straight. The smooth outer bark of the sweet or cherry birch is spicy and aromatic; that of the white birch of Europe is used for tanning; that of the paper birch splits into thin sheets having a good writing and drawing surface. Several varieties of the white birch are cultivated for ornamental purposes. Birch is used for construction of furniture, interior trim, flooring, and wood kitchenware. It is well adapted as a base for an enamel coating.

Yellow Poplar—This is a general utility wood which has largely taken the place of white pine. It is light, brittle, soft, easy to work, nails very well, has medium strength, and does not warp badly when handled properly. The pith rays are very noticeable, but it is not commonly used for decorative purposes. The color is greenish or yellowish brown. Yellow poplar is a good wood to keep in stock for all sorts of purposes and is an ideal wood for carving.

CABINETMAKING WOODS

The requirements for woods used in cabinetmaking and furniture are: stability, or ability to keep its shape without shrinking,

swelling, and warping; ease of fabrication, surfacing, and finishing; suitable strength and grain characteristics; and pleasant and attractive in appearance.

Black Walnut—This is one of the most beautiful of native woods. The color of the heartwood is light to dark chocolate brown, whereas the sapwood is pale brown. It warps only moderately, has great strength, and is medium heavy. Black walnut splits with some difficulty, takes and holds nails well, and is very easy to work. It is used chiefly in all types of solid and veneered furniture, cabinetwork, interior finish, and gun stocks.

Mahogany—There are a number of species under the general name of mahogany, all of which are imported. The different varieties are somewhat alike in color—a reddish brown. The annular rings vary considerably in hardness, difficulty of nailing, and shade of color. The grain is likely to be variable, causing an attractive reflection of light. It is used for interior finish, furniture, handrails, patterns, etc.

Cherry—The color varies from almost black through shades of red to yellow. The grain is straight, close, and fine. The wood is of medium strength, the warpage and shrinkage are minor, and it splits readily but is easily worked. It is used for cabinetwork, furniture, and to some extent for patternmaking. Cherry is an excellent wood for turning, but because of its relative scarcity it has become quite expensive.

Gum—This wood is heavy, hard, tough, compact, and close grained. It has a beautiful chocolate color varied with uneven deposits of coloring matter, has an even texture, and polishes well. It is comparatively easy to work, is a good wood for carving, and nails fairly easily. Gum, however, twists and warps more easily than any other common woods. It is used to some extent for furniture, and it is a popular wood for making small articles for household use.

White Ash—This is a heavy, strong, elastic, coarse-grained hardwood. It is used to some extent in interior trim and furniture and very often for such articles as tool handles, oars, and barrels.

Cypress—One of the most durable of woods is light, hard and of a very close grain. It nails well and is capable of high polish. Its color is light, clear brown often tinged with red and gray. Be-

cause of its beauty, it is a desirable wood for interior finish and some types of furniture.

White Oak—This wood is very strong, quite heavy, elastic, and hard. It is rather hard to work or nail and checks and warps considerably unless carefully seasoned. The color is light brown; it is capable of receiving a high polish and is extremely attractive when carefully worked. The rings are plainly defined by pores which, when stained, make a pleasing contrast with the "summer" wood, or pith rays. It is commonly used for furniture and interior finish.

Hickory—This is a tough, heavy, hard, and very strong wood, being dark brown in color with the sapwood nearly white. It splits with great difficulty and is almost impossible to nail. Because of these characteristics, it is often used in the tool industry for handles for axes, picks, sledges, hatchets, and the like.

CHAPTER 20

Common Wood Joints

In woodwork the term *joint* means the union of two or more smooth or even surfaces permitting a close fitting or junction, as in a joint between two boards. In all jointing, the aim is to obtain a strong joint without weakening any part unduly by the removal of too much wood. It requires considerable skill to make a good joint, especially some of the more complicated forms, because the parts must be shaped to dimensions with precision so that the fit will be accurate. There are many wood joints, all of which may be divided into the following classifications, according to the manner in which the joining pieces are brought together, as:

1. Plain or butt joints.
2. Lap joints.
3. Mortise-and-tenon joints.
4. Dovetail joints.

The term *plain* or *butt joint* signifies a joint in which the end or side of one piece is placed or "butted" against the end of the other. A *lap joint*, on the other hand, denotes a joint in which the two pieces to be joined lap over or into one another, hence the name lap joint. *A mortise-and-tenon joint* consists of a mortise or hollowed space, usually rectangular, into which a tenon is fitted. Mortise-and-tenon joints are frequently called simply tenon joints. The operation of making mortise-and-tenon joints sometimes is termed tenoning which also implies mortising.

A dovetail joint is so termed because of the shape of a dove's tail. It consists essentially of a flaring tenon or tongue and a mortise

or socket into which it fits tightly, making an interlocking joint between the two pieces. There is a great variety of joints which may be included under each of the foregoing classifications, each of which will be fully explained.

PLAIN OR BUTT JOINTS

Under this general classification, the following joints may be included:

1. Straight or plain-edge.
2. Dowel pin.
3. Splined or feather.
4. Beveled spline or miter.
5. Beveled plain-edge.

Straight or Plain-Edge Joints—This is the simplest form of joint and has many uses, particularly in applications where several pieces are required to form a flat surface, such as in a variety of cabinetwork, tables, desk tops, bookcases, etc. To make a close-fitting butt joint, however, requires skill in the use of the plane. It may be made with or without the use of glue, as conditions require.

To make the side joint, first square and straighten the edges with jack, fore, and jointer planes, frequently testing the surfaces with a try square and fitting the pieces until a perfect fit is obtained as in Fig. 1. Then if glue is to be used, apply it to each of the edges, and clamp them tightly together. When dry, the joint will be permanent. Many of the prepared glues on the market are very satisfactory for gluing wood joints.

Dowel Joint—This joint may be considered a substitute for mortises and tenons in the legs and rails of chairs and tables and in numerous other furniture applications. If well made and not exposed to the weather and extreme temperature changes, it is an excellent substitute for the mortised joint. A dowel joint is simply a butt joint reinforced by dowels which fit tightly into holes bored in each member to align them with each other. Fig. 2 shows various types of joints ready for assembly with dowels inserted. Success in making a dowel joint depends upon the accuracy of

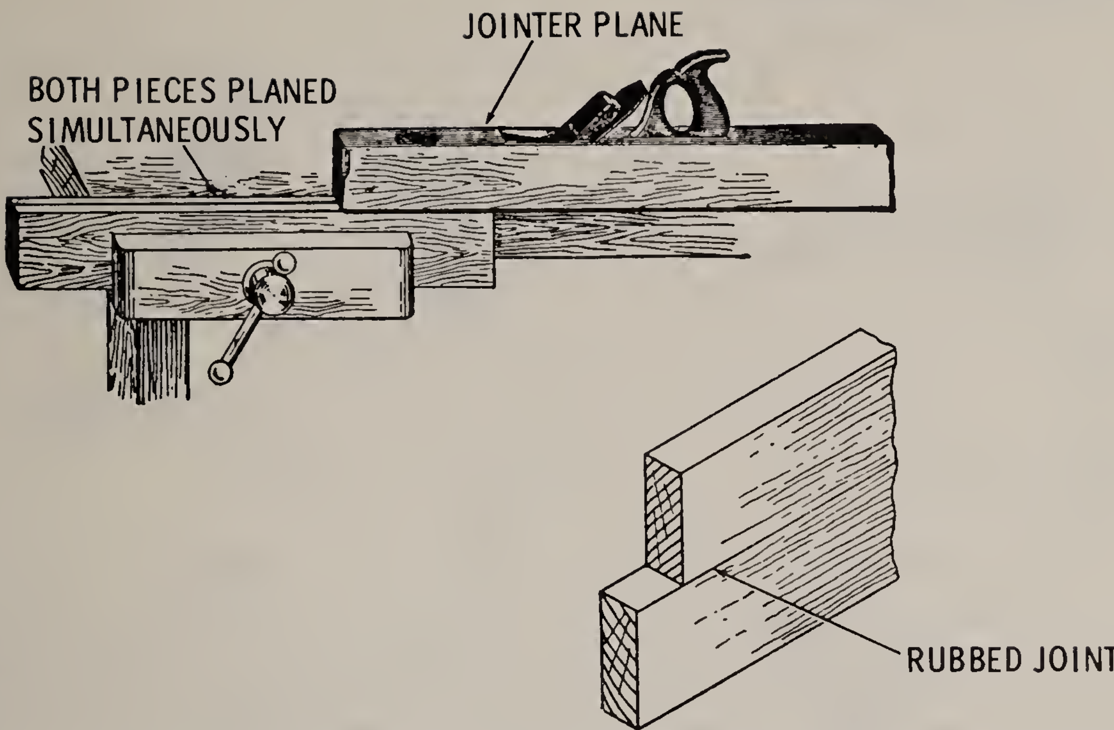


Fig. 1. Method of planing both edges together to obtain a straight-butt side joint. This requires a great deal of skill in planing and it is necessary that the plane be straight on the edge and carefully sharpened and adjusted. After planing, the edges are glued and rubbed together as illustrated.

marking and boring the holes for the dowels. Unless the holes are bored in perfect alignment, it will be impossible to assemble the pieces, or when assembled, the pieces will not align properly. A doweling jig is relatively inexpensive and when used properly insures accuracy in marking and boring holes for dowels.

Dowels can be purchased in almost any hardware store. They consist essentially of round wooden pegs cut a trifle shorter than the sum of the depths of each of the two holes into which they are set. Each of the dowels should be slightly chamfered with a knife or dowel sharpener to prevent binding when they are forced into place. Usually each dowel also has a small "vee" or screw-type groove cut on it to permit the escape of excessive glue and imprisoned air when the dowel is driven home. These grooves also prevent splitting of the work, which is important, particularly when joining small or narrow pieces together. Prefabricated dowels of the type purchased in hardware stores are usually made of birch or maple and come in various diameters from ¼ inch to ¾ inch in three-foot lengths. In gluing dowels, the glue should be placed both in the holes and on the dowels.

Splined or Feather Joint—In this form of joint, a groove is made in each of the pieces to be joined and a spline or feather

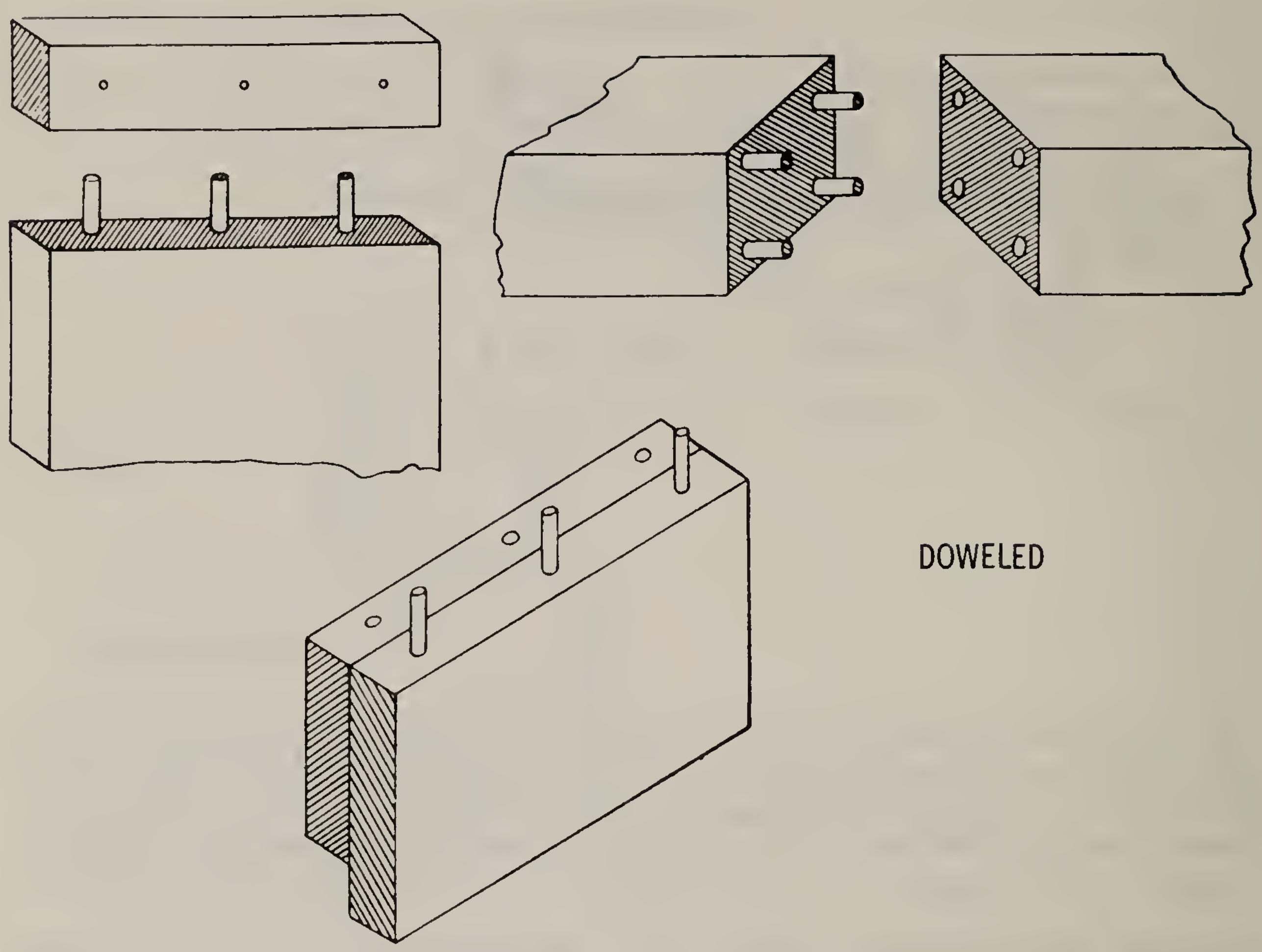


Fig. 2. Method of joining wood by means of dowel pins.

made as a separate piece is inserted as shown in Fig. 3. This form of joint has been largely replaced by the familiar tongue-and-groove joint. The main reason for the use of the splined or feather joint is that when two pieces of softwood are joined, a hardwood spline (which should be cut across the grain) will render the joint less liable to snap than if a tongue were cut in the softwood lengthwise with the grain. This form of joint is usually glued, and the groove is made by a special tool known as a "plow-and-tongue," or combination plane.

Beveled Splined Joints—Joints of this type are often used in making picture frames and other articles of wood having various central angles such as shown in Fig. 4. In making multimitered splined joints of this sort, it is important to lay out the work properly and to use squared stock of equal width, shape, and thickness. To make a splined miter joint, such as that used in the fabrication of picture frames, special miter machines or simple miter boxes are available. In setting the miter machine or other device for the desired angle, it is important to note that the proper

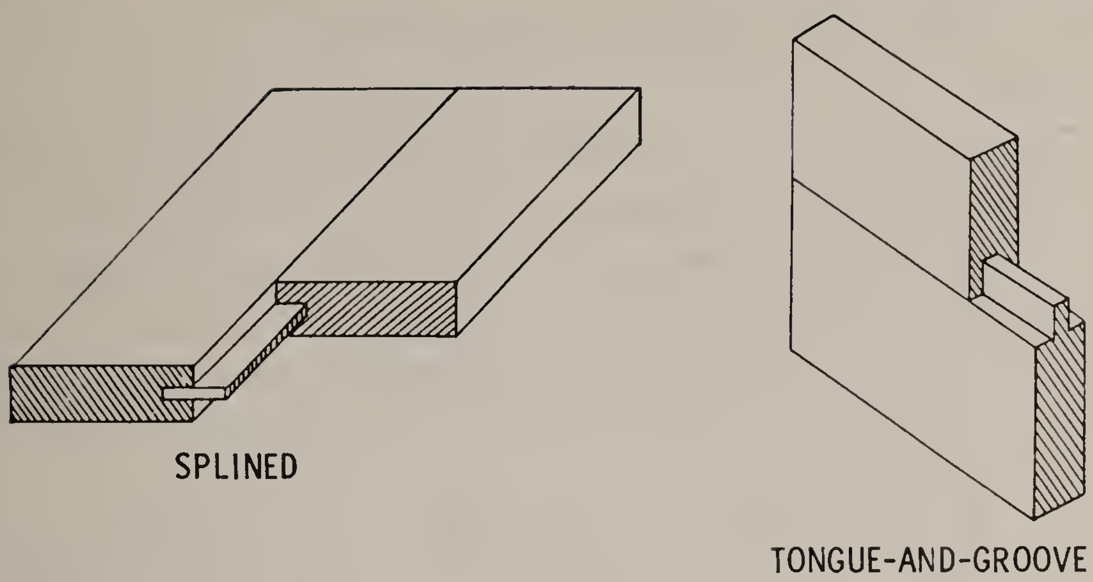


***Fig. 3.** Typical splined and tongue-and-groove joints. To obtain increased strength, joints of these types are usually glued. When making splined joints, it is important that the spline or feather be of the same type of seasoned wood as the boards to prevent parting due to unequal expansion or contraction when exposed to temperature changes.*

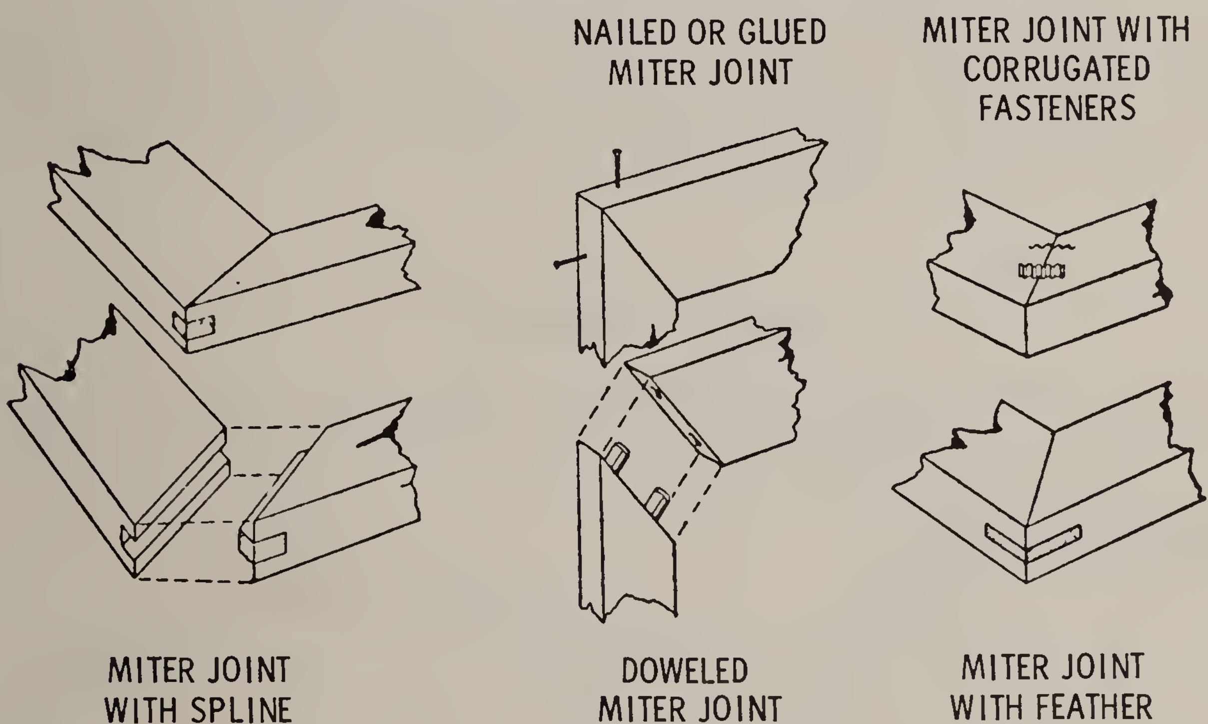


***Fig. 4.** Miter joints suitable for picture frames. Joints of this sort should be reinforced with glue for added strength.*

angle depends upon the number of sides involved. For example, in all four-sided square or rectangular objects, the miter or angle-measuring device should be set at a 45-degree angle, whereas the miter angle for a regular hexagon should be 60 degrees. To obtain the miter angle for any regular polygon (having sides of equal length), the following simple formula may be used.

$$\text{miter angle} = 90 - \frac{360}{2N}$$

where N equals the number of sides required.

Inserting various values in the foregoing formula, we obtain the miter angle for the four-sided square as 90 – 360/8 or 45 degrees; for a pentagon (5-sided figure), the miter angle is 90 – 360/10 or 54 degrees; for a hexagon (6-sided figure), the miter angle is 90 – 360/12 or 60 degrees, etc. Finally, if it is desired to make a spline-joined object having 14 equal sides such as that illustrated in Fig. 5, the miter should be set at an angle of 90 – 360/28 or 77.143 degrees. To obtain the necessary strength in the joined surfaces, the butting sides of the various pieces, together with the splines, should be carefully glued and clamped prior to finishing.

Beveled Plain-Edge Joints—These joints differ from the previously described splined joints mainly in the omission of the splines. Fig. 5 illustrates the makeup of such joints which are used to some extent where strength is not an important factor and where the thickness of the material permits an extensive glued surface. In joints where additional strength is desired, splined or doweled joints are recommended.

LAP JOINTS

Joints of this type are generally employed in articles where a great deal of strength is required and are used in all types of

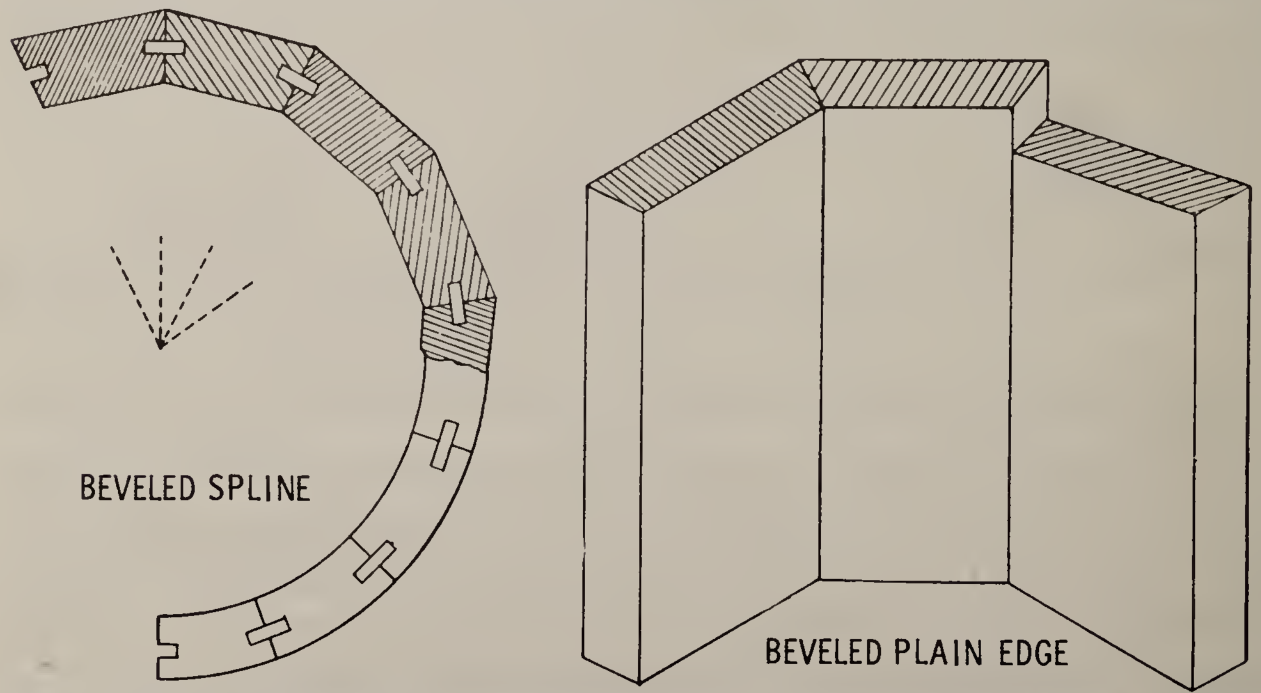


Fig. 5. Beveled-spline and plain-edge joints. The beveled-spline method of jointing is often used when it is desired to obtain a cylindrical surface from a regular polygon.

cabinetmaking, desks, drawers, etc., and in carpentry work such as in the fabrication of frames for windows, doors, and the like. There is a great variety of these joints.

Halved or Bridle Joints—These are lap joints having each of the pieces halved and shouldered on opposite sides, so that they fit into each other. The lap joint is the simplest joint in cabinetwork. Because it is strong and easily made, it is much used in constructing skeleton framework in carpentry, for facing of

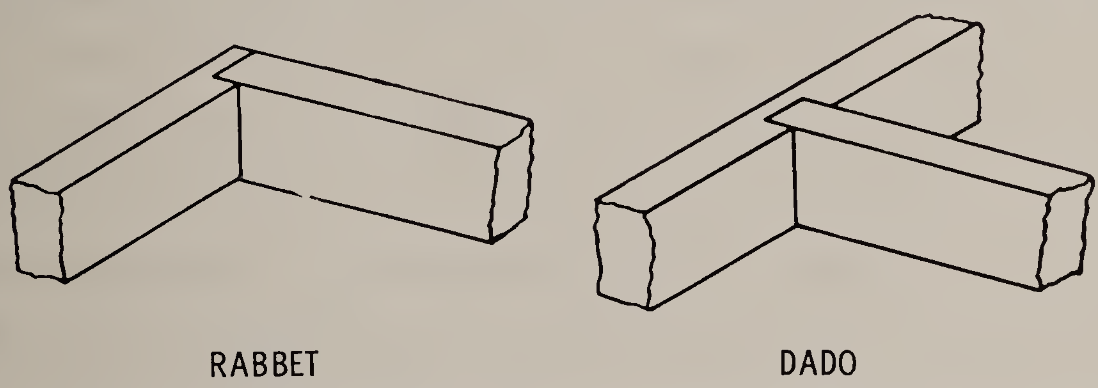


Fig. 6. Typical rabbet-and-dado joints. A rabbet-and-dado joint is one of the simplest of lap joints and is made in the same manner as a plain dado, except that a rabbet is first laid out and cut on the end of the housed piece. This type of joint is frequently used for the corners of boxes.

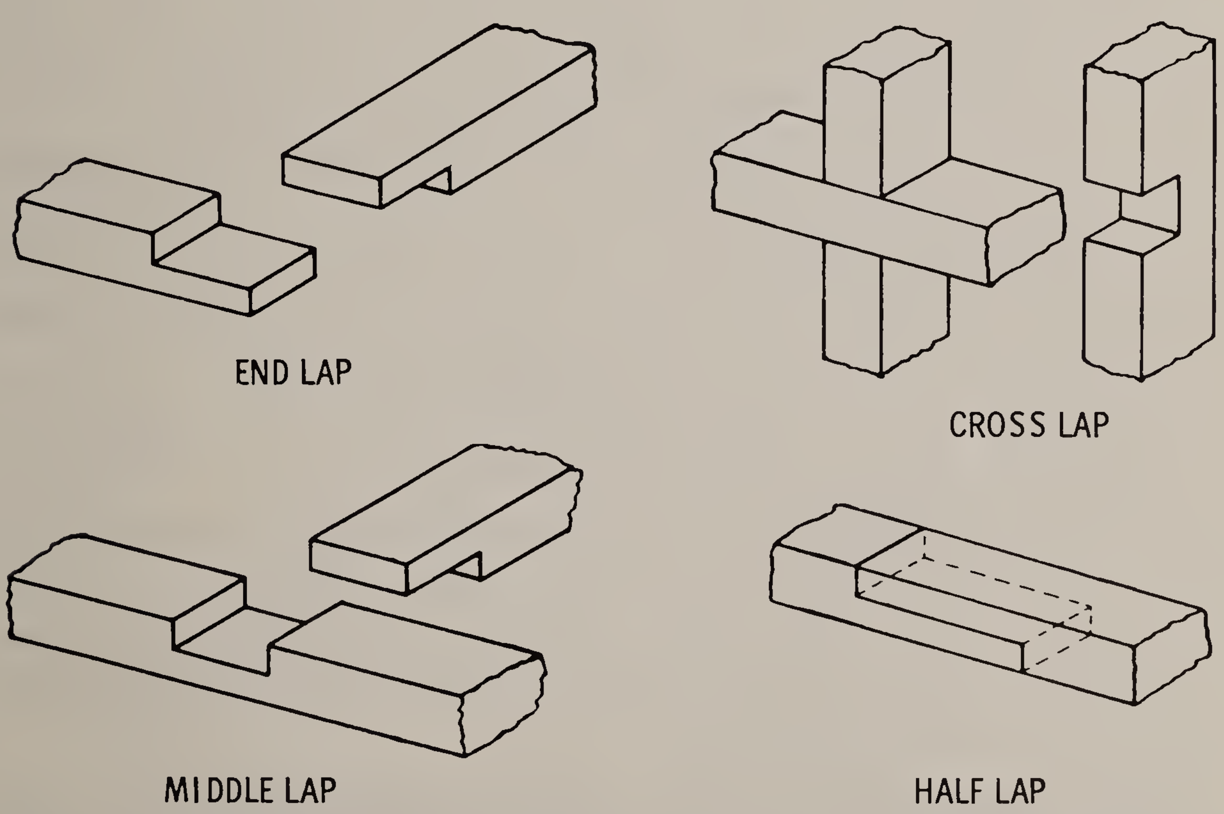


Fig. 7. Typical lap joints. The overlapping feature furnishes a greater holding area in the joint and is therefore stronger than any of the butt or plain joints. A half-lap joint, sometimes called a scarf joint, is made by tapering or notching the sides or ends of two members so that they overlap to form one continuous piece without increase in thickness. The joints are usually fastened with plates, screws, or nails and strengthened with glue.

doors, and the like. Half-lapped joints derive their names from the methods of joining, such as:

1. End lap.
2. Cross lap.
3. Middle or center lap.

Fig. 7 serves to illustrate the common types of these joints. Since they are very simple to make, the beginner at the trade should logically commence with making one or several of these joints. In making a half-lapped joint, the stock should be planed to width and thickness. The distance that the pieces are to lap each other is laid off with the marking gauge, thus giving a layout line on the face side of one piece and on the opposite side of the other. These lines should be squared halfway through the thickness on each edge.

The gauge should be set to half the thickness of the stock and the marking done on the edges and ends from the face side. This is important, as one line is gauged from the face from which material is removed, and the other from the face that is to remain intact, the lap being formed on the opposite face.

This method will make the section that remains on one piece equal to the section removed from the other piece and bring the joint exactly flush on the face regardless of whether or not the gauge was set exactly to half the thickness. In making all joints, it is always good practice to gauge from face sides, as this will bring one face of the joined pieces flush, even if the stock is of varying thickness. In making an end lap, the face cut should be made first by placing the piece in a vise and cutting from the end back to the shoulder line, leaving about 1/16 inch for paring. The shoulder cut is then made, usually leaving about 1/16 inch to pare back to the line. This paring is unnecessary if the shoulder cut is made with the back saw.

When removing the waste in making a cross-lap joint or one-half of a center-lap joint, the work can be facilitated by making a series of saw cuts and removing the waste with a chisel. When properly made and fastened with glue or screws, the lap joint makes a very strong joint.

MORTISE-AND-TENON JOINTS

Many variations of the mortise-and-tenon joint are used in cabinetwork, differing in size and shape according to the requirements of the project for which each is used. Among the more common joints in this classification are:

1. Stub tenon.
2. Through tenon.
3. Haunched tenon.
4. Open tenon.
5. Double tenon.

The tenon may project only partly into or completely through the mortised work. When the tenon does not extend through the mortised piece, it is called a *stub* or *blind* tenon; when it projects

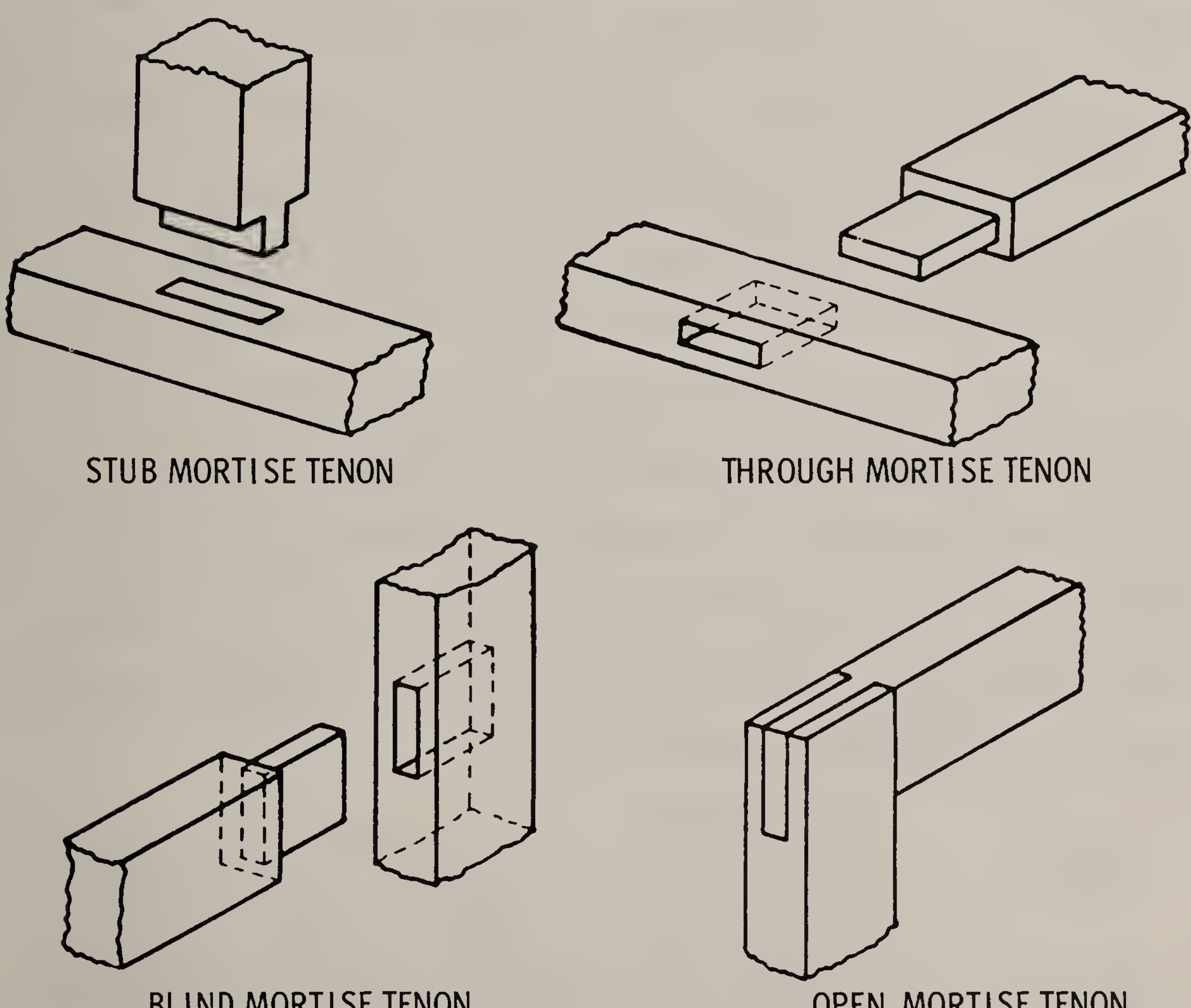


Fig. 8. Common mortise-and-tenon joints. This is one of the most frequently used joints in furniture and cabinetwork; while this joint is made in great many different ways, it generally consists of one member being cut away on the end to form a narrow projection which can be inserted in a corresponding rectangular hole cut in the other member.

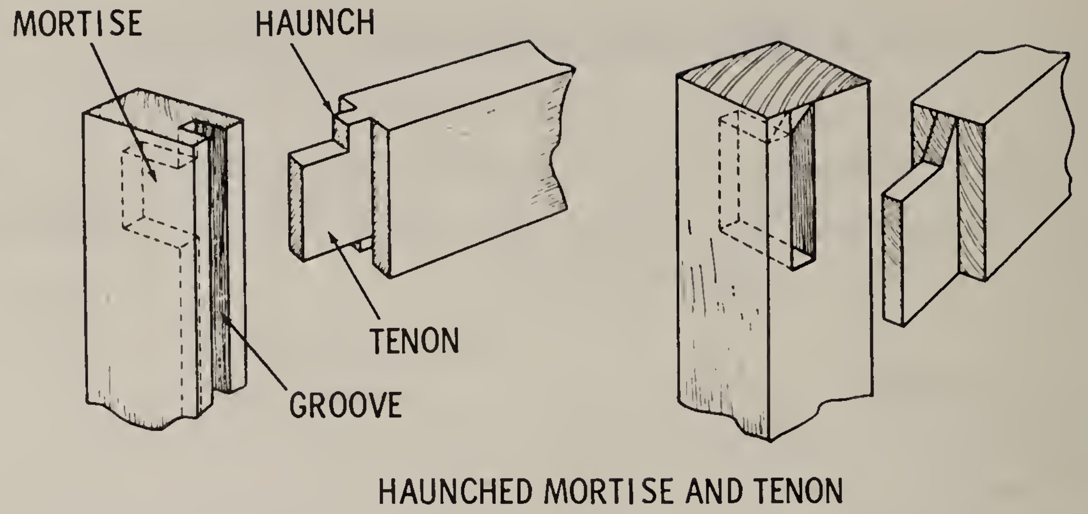


Fig. 9. Haunched and mitered mortise-and-tenon joints. Various shoulder, haunched, and barefaced-tenon joints are used in connecting crosspieces to outside rails of various cuts and shapes. The long and short shoulder joint is commonly used in window and screen frames, bureau drawers, and glass-front cabinets for connecting the rails to a rabbeted frame.

completely through, it is called a *through* tenon. When the entire mortise does not extend to the full depth and the shallow portion is filled by a projection of the tenon left for this purpose, it is called a *haunched* tenon joint. When the joint is open entirely through to the end, it is called an *open* tenon or *slip joint.*

In cutting a mortise, select a chisel as near the width of the mortise as possible. This chisel, especially for large work, should be a framing or mortise chisel. Bore a hole the same size or width of the mortise at the middle point. If the mortise is for a through tenon, bore halfway through from each side. In the case of a large mortise, most of the wood may be removed by boring several holes. In cutting out a small mortise with a narrow chisel, work from the hole in the center to each end of the mortise, holding the chisel at right angles to the grain of the wood. At the ends, the chisel must be held in a vertical position having the flat side facing the end of the mortise.

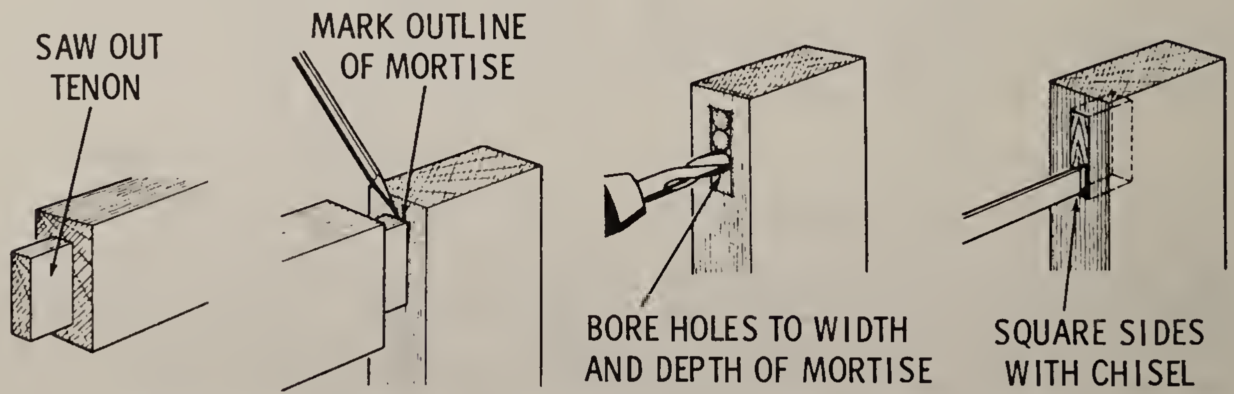


Fig. 10. Method of laying out and making a small mortise-and-tenon joint.

A through mortise is laid out on both edges of the piece and cutting is done from each edge with a mallet and mortising chisel, meeting in the center. After cutting, test the accuracy of the sides by using a try square; this will test the accuracy of the work. The cutting of the tenon requires the same general operations as the half-lapped joint. Mortise-and-tenon joints are used exclusively in the construction of tables, desks, and other cabinet pieces which must withstand hard usage.

Wedged mortise-and-tenon joints are laid out and cut in the same manner as other mortise-and-tenon joints except that the mortise is given a flare on the side away from the tenon shoulder. When the joint is glued up, wedges with glue are driven between the tenon and the end cheeks of the mortise. Sometimes two saw kerfs are made in the tenon and the glued wedges driven into them.

DOVETAIL JOINTS

The dovetail joint is often termed the aristocrat of wood joints. It is one of the strongest of all wood joints because of the tapering shapes of the sides of the pins and tails with their numerous interlocking surfaces. Dovetail joints are generally used in furniture drawers, in box construction, etc., where strong dependable joints are required.

The projections which have the taper on their faces are called *dovetails*, whereas the projections whose ends are tapered are called the pins. The spaces remaining between the tails and pins are called the *mortises*. A joint consisting of but one dovetail is called a *single dovetail;* a joint consisting of a series of dovetails and corresponding pins is a *compound dovetail*. Depending upon the construction method used, all of the dovetail joints may be classified as:

1. Single dovetail.
2. Compound dovetail.
3. Half-blind dovetail.

Dovetail joints are somewhat difficult to make, but they have great strength because of the flaring shapes of the sides of the pins and the tails. The angle of the dovetail should not be too

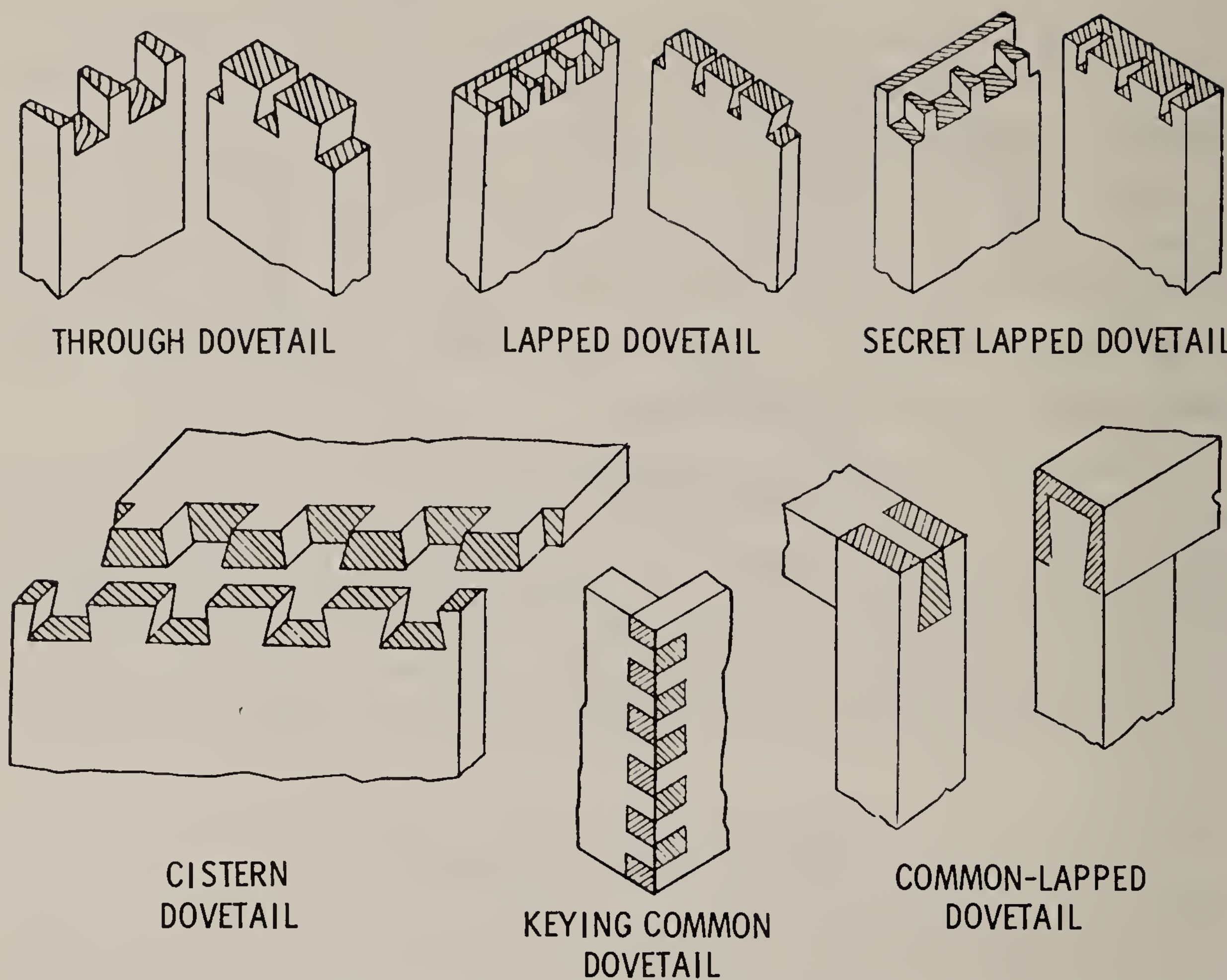


Fig. 11. Various types of dovetail joints. Dovetail joints are used principally in cabinetmaking, drawer fronts, and furniture work. It is a partly housed and tapered form of tenon joint in which the taper forms a lock which holds the part securely together.

great or the joint will be weak because of the short grain at the corner. The angle may be laid out by squaring a line from the edge of a board, measuring five, six, seven, eight or nine inches along

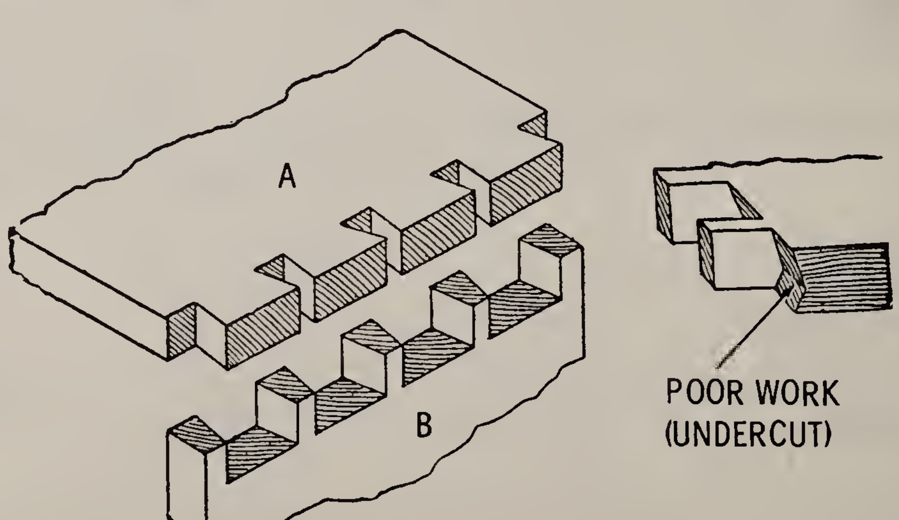


Fig. 12. Multiple-dovetail joint and detail joint poorly cleaned out.

it from the edge, then measuring one inch from the line along the edge and connecting the points. The hypotenuse or long leg will make an acute angle which will be approximately correct for most dovetail work.

The angle selected may be transferred to the work by an adjustable "T" bevel or by means of a suitable template. It should be noted that the strongest dovetail joints are those in which the pins and the dovetails are of the same size, but for the sake of appearance the tails are often made larger than the pins.

Multiple-Dovetail Joints—To make a multiple-dovetail joint such as shown in Fig. 12, both edges are made true and square, after which a gauge line is run around one board at a distance from the end equal to the thickness of the other, which is similarly marked. Now, two methods are followed. Some workers mark and cut the pins first; others the sockets. In the first method, the pins are carefully spaced and the angles of the tapered sides marked with the bevel. Saw down to the gauge line and work out the spaces between with a chisel and mallet. Then put B on top of A (Fig. 12), and scribe the mortise. Square over, cut down to the gauge line, clean cut, and fit together.

The second method is to first mark the sockets on A (sometimes on common work the marking is dispensed with), the worker using his eye as a guide; then run the saw down to the gauge line, put A on B, and mark the pins with the front tooth of the saw; cut the pins, keeping outside of the saw mark sufficiently to allow the pins to fit fairly tight; then both pieces may be cleaned out and tried together.

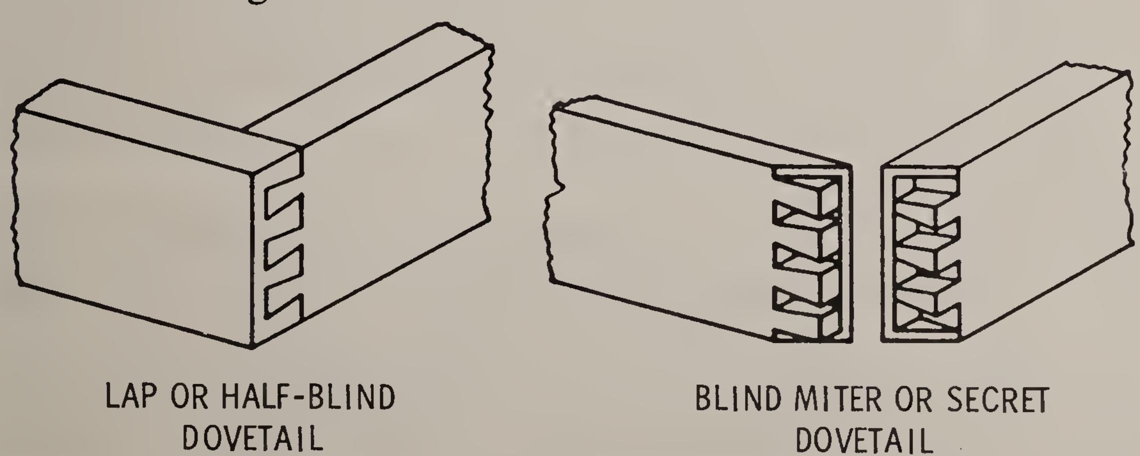


Fig. 13. Half-blind dovetail joints respectively. The half-blind dovetail joints are used in the best grades of drawer and cabinetwork. The joint is visible on one side and not on the other. It should be exceptionally well fitted because of the frequent pull on the front piece.

In cleaning out the mortises and the spaces between the pins, the woodworker must cut halfway through, then turn the board over and finish from the other side, taking care to hold the chisel upright, and not so as to cut under as shown in Fig. 12, which is sometimes done to insure the joint fitting on the outside.

Half-Blind Dovetail Joints—This type of dovetail (Fig. 13) is commonly used in the fronts of drawers and is similar to the multiple type except that the dovetails do not come through and only the ends of the pins can be seen on the side of the joint. Since the sides of the drawers are usually thinner than the front, the gauge is set at the thickness of the side piece and a shoulder line is marked on the end of the front piece of the drawer from the work face to mark the overlap of the dovetails.

The shoulder line on the face of the front piece and the shoulder line for the dovetails on the side piece may be made with the try square or with the marking gauge with a single setting. The pins and sockets are laid out in the same manner as previously described; either the pins or the dovetails may be laid out first. The sides of the pins need not be sawed all the way through because the cuts extend only part way through the wood.

GLUE AND GLUING

When making joints which are to be glued, care must be exercised to have the edges of the pieces to be joined perfectly square, so that when fastened together, the faces will present a straight line and not be hollow or rounded when placed together. To obtain true surfaces, pieces to be joined should be tested with a straightedge and try square.

Long edge joints, when glued, are put together either by being rubbed or squeezed together by clamps. When the two edges match throughout their length and no cracks show on either side, the glue may be spread in the manner shown in Fig. 14. A satisfactory way of gluing up rubbed joints is to fasten one piece securely in the bench vise and place the edge of the other piece against it. Apply glue thoroughly to both edges and carefully place them together.

To rub into position, take hold of the top piece at each end and rub steadily with a back and forth lengthwise movement as shown in Fig. 14. As the air and glue are expelled, the piece will move less freely and strokes will gradually shorten and finally cease as the reference marks are brought into line. If the joint is not clamped while drying, stand it against a flat surface inclined at a slight angle as illustrated in Fig. 14. Make sure that the joint lies flat against the inclined surface to insure a good strong joint.

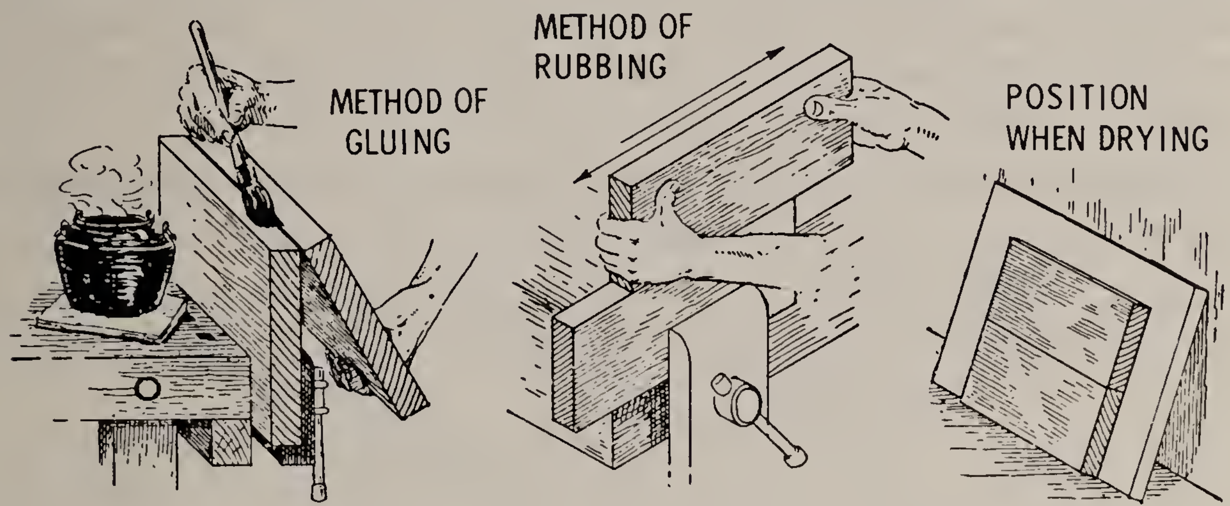


Fig. 14. Rubbed joints and methods of assembly.

Clamping—Thin material or materials having an extended surface should be put between clamps on a flat surface with a weight on them to prevent springing. There are many forms of clamps and devices for holding work firmly in place while the glue sets. When bar clamps or pipe clamps are used, small pieces of softwood should be placed against the surfaces of the work to protect them from being marred by the clamp edges.

Types of Glues—Animal glue is always used hot. Fish and vegetable glues come in liquid form and are used cold. To waterproof animal glue, about one percent of potassium bichromate is added while the glue mixture is hot. Good cold-water glues are also available, such as casein and resin glues. The latter is waterproof and hence is used in marine and other work where the material is to contact water.

Preparing the Glue—In the preparation of animal glue, the most important part is to have a clean glue pot. Glue pots are always of the double boiler type to prevent burning the glue. These pots range from the simple container fitting into a larger vessel containing water to the more elaborate steam and electrically

heated pots. An electric glue pot is perhaps the best because there is no danger of overheating.

To prepare the glue, break in small pieces as much glue as will be needed the following day and soak it in water overnight or for a period of about twelve hours. Mix only a small quantity at a time because it is best to prepare glue only as required. Have sufficient water to cover the glue. When it is softened, heat it to about 150 degrees, being careful not to boil it. Boiling will markedly weaken the glue, as will the addition of too much water. To prevent evaporation, the heating process should be discontinued as soon as the gluing is finished.

When the glue is properly melted and heated, it should run from the brush in a stream somewhat thicker than milk. Almost any

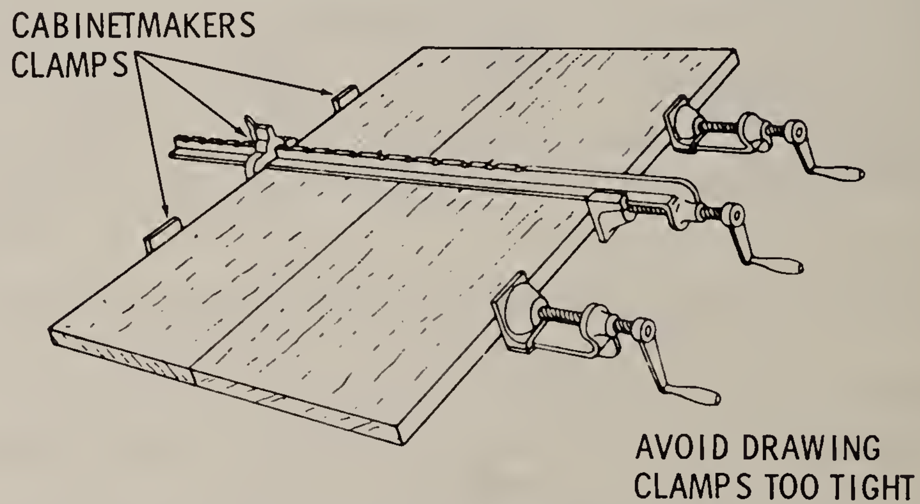


Fig. 15. Method of clamping boards together after gluing by means of a set of cabinetmaker's clamps. There are many forms of clamps and devices for holding work firmly in place until the glue sets.

ordinary paint brush may be used for application of glue. It is well to keep a small stick in the glue pot for an occasional stirring and also for wiping off the brush.

Planning the Work—During the gluing process it is important to plan the work and to have everything in readiness because a delayed action in gluing will greatly weaken the finished product. Have the work and clamps arranged for instant use. Place together the pieces that are to be glued, and see that they fit properly and will quickly adhere to one another after the glue has been applied. Warm the joints so that the glue will penetrate into the wood.

It should be noted that glue penetrates the wood as a liquid, and as it hardens holds the wood together in a kind of locking

action between the wood fibers. The newer type glues react chemically with the wood fibers. Common practice in gluing calls for a proper division of the work. This will greatly aid in getting the clamps on quickly and in truing the joints.

CARPENTRY JOINTS

These are used in heavy construction such as in the building of homes and outdoor construction work. They are employed mainly in splicing or joining heavy pieces of timber. Thus, all connections between pieces of timber are classified either as joints or splices. *Joints* are connections between two pieces of timber which come together at an angle, whereas *splices* are connections between two pieces of timber which extend in the same line. Joints, as used in carpentry, are classified into a number of types, as:

1. Square.
2. Plain.
3. Oblique.
4. Miter.

The carpenter should be familiar with each type and know when to use each to secure the best result.

The Square Joint—This is the simplest of all joints and consists of placing the pieces of timber together with the end of the one against the side of the other and nailing them firmly together as shown in Fig. 16. The butt end should be square and the joined end smooth so that the pieces will be perpendicular to each other. As noted in the illustration the nails are driven diagonally through both pieces, an operation known as "toenailing." The nails are driven home, or flush, using nails to suit the size of timber to be joined. This type of joint is employed where caps and sills are placed upon posts. It is used for compression but not for tension.

The Plain Joint—This type of joint can be used for either compression or tension but is not very strong. It is suitable in hasty construction work and is made by lapping one piece over the other and nailing the two together as shown in Fig. 16. There is no prescribed angle for this connection and it requires no square ends or straight edges.

The Oblique Joint—This joint is made when two pieces of timber do not meet at right angles. Bracing is a typical application for this joint. As noted in the illustration, one piece is cut at an angle to fit the other and they are nailed securely. The joint depends upon the nailing for strength and it should not be used where great strength is required. The size of the nails depends entirely upon the size of timber used. Too many nails will weaken rather than strengthen the joint.

The Miter Joint—A miter joint is a joint between two pieces of timber joining one another at an angle, usually 90 degrees. This joint is used at corners where the square joint is unsatisfactory. This, as well as the oblique joint, is used extensively for bridge building and other supporting structures. For a 90-degree joint, each piece is cut at an angle of 45 degrees, so that when the two

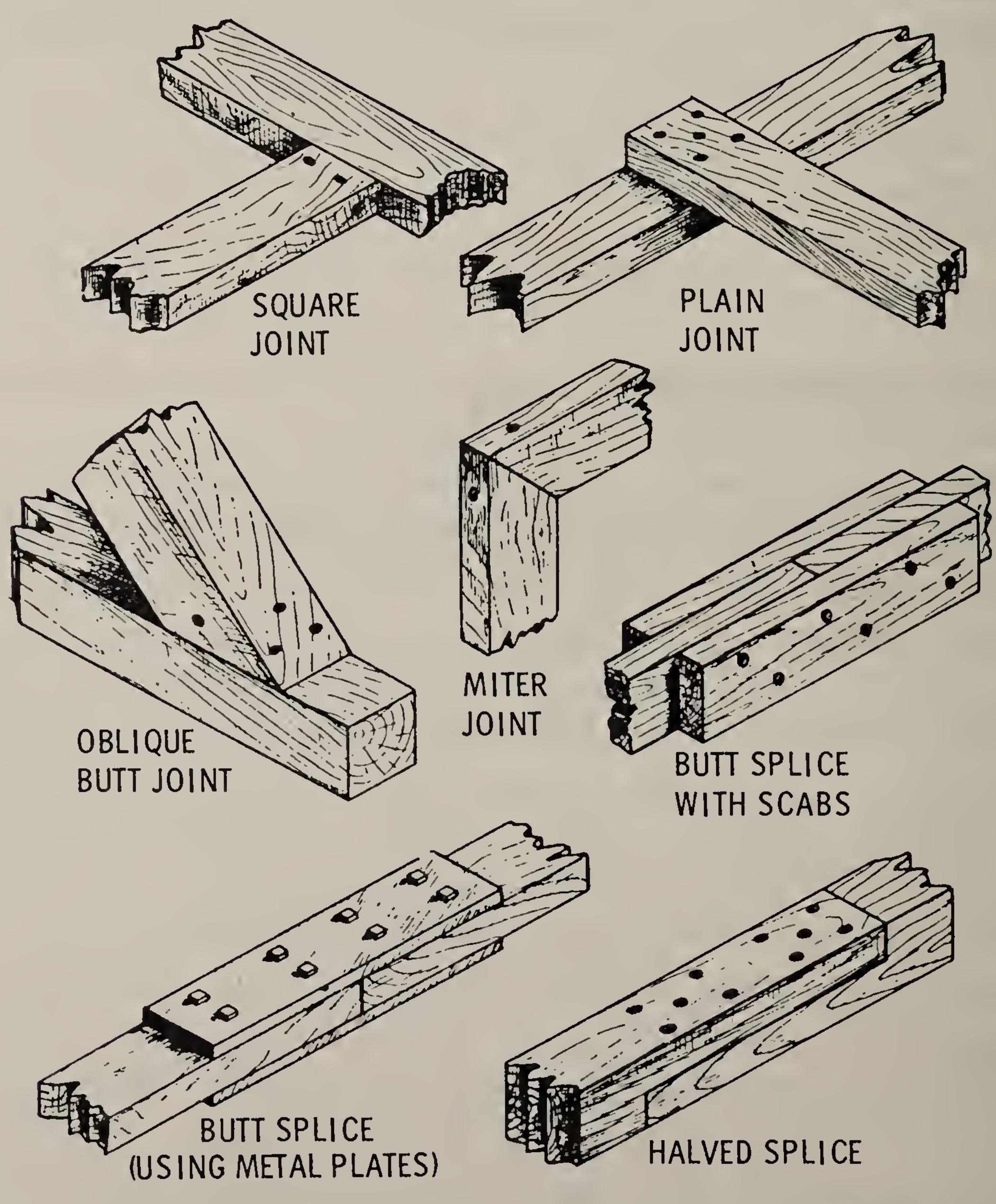


Fig. 16. Various types of joints and splices.

pieces are put together they will form an angle of 90 degrees. For making a miter joint at any angle, the angle of cut should be the same for both pieces.

SPLICES

The function of a splice is to connect two or more pieces of timber in such a way that the joint will be as strong as a single timber of equal size. Depending upon the duty involved, splices may be divided into three distinct types, as:

1. Splices for compression.
2. Splices for tension.
3. Splices for bending.

Splices for Compression—This type of splice is designed either to support weight or to exert pressure. There are several types of splices for compression, although the "fished" and the "half-splice" are the most common. The *fished splice* consists essentially of two pieces of timber that are squared at their ends and butted together with two short pieces fastened on each side of the splice. These short pieces (usually called fishplates or scabs) serve to keep the splice straight and prevent buckling. The term "fishplates" usually refers to metal plates used for splicing and are commonly fastened with bolts or screws as illustrated.

The wood plates commonly called "scabs" may be fastened with bolts, nails, or with ring connectors. For best results, the nails should be staggered and driven at an angle away from the splice. The *halved splice* is better for direct compression and when combined with fishplates or scabs may be used where some tension is required. This splice is made by notching each piece halfway to any desired length and placing the two halved sections together with nails or bolts as illustrated. The splice may be further strengthened by using either fishplates or scabs as illustrated in the fished type of splice.

Splices for Tension—There are several types of tension splices, the most common and simplest type being the square splice. These splices are made to resist tension and are employed in tension members, such as trusses, braces and joists where the available material is too short. The *square splice* is a modification

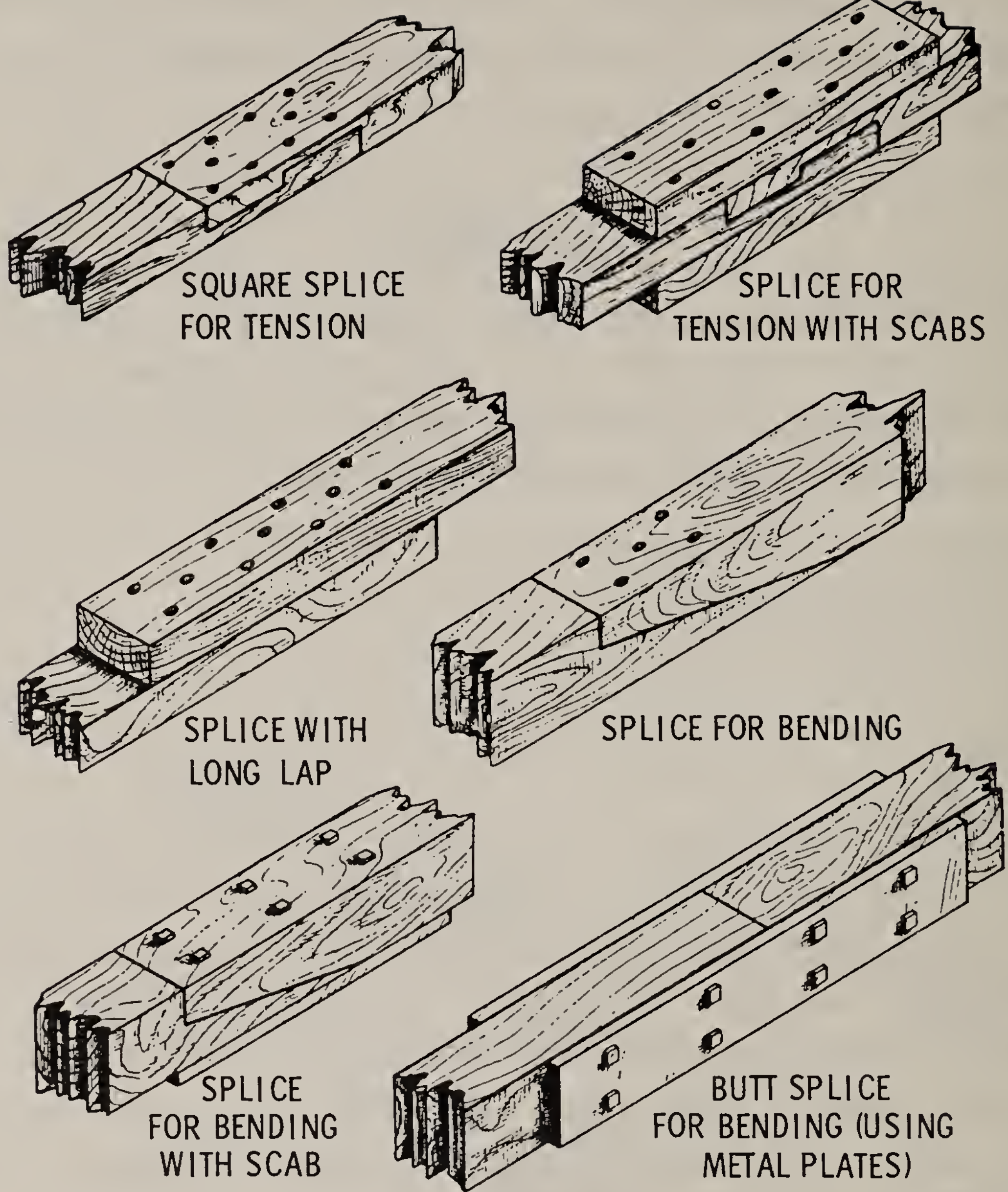


Fig. 17. Tension and bending splices.

of the halved splice. It consists of two timbers notched together as shown in Fig. 17, and although this type of splice requires more time to make, it is very efficient. When the splice is fastened by fishplates or scabs with bolts or nails, its strength is greatly increased.

Splices for Bending—Sometimes a piece of timber subjected to a bending stress must be spliced. When a horizontal piece of timber supports a weight, the upper part is under compression which has a tendency to crush the fibers, while the lower part is in tension which has a tendency to pull the fibers apart. To overcome this difficulty, a splice must be made which will combine the features of the compression and tension splices. Such a splice is shown in Fig. 17.

It should be noted that the parts are scarfed together in the conventional manner, but in this case the upper piece is cut off square to offer the maximum resistance to crushing. The under piece is beveled on the end because there is no tendency to crush the timber. To overcome the tendency to pull apart at the bottom, reinforcements consisting of a fishplate or scab will greatly strengthen the splice. Where only moderate bending stresses are involved, a butt joint with fishplates or extra long scabs may be used. In the case of a heavy timber, through bolts make for a better and more dependable joint.

CHAPTER 21

Painting

Application of paint to the finished product is commonly accomplished by two methods, namely:

1. Brushing.
2. Spraying.

Both methods of application will give satisfactory results, and although brushing is rather time-consuming compared to use of the spray gun, it has certain advantages in simplicity of equipment. When properly applied, the paint job is fully equal to and as durable as that obtained when using a spray gun.

Brushes to Use—The character of the work usually determines the type of brush to be used, although it is an odd fact that choice of tools differs widely in various parts of the country. Quality bristle brushes, however, are a prime necessity for good painting and decorating work. This is a point which should always be remembered.

One of the best all-purpose finishing brushes is an "XXX" black China bristle, full chisel brush, about 2½ inches wide. The "XXX" on a brush actually means that the bristles are made up in three rows or thicknesses. Double and single brushes are proportionally thinner in body and are commonly used on curved surfaces where a great deal of flexibility is required.

Softer brushes, such as those made from goat bristles, badger, sable, etc., can be used to advantage for flowing on quick-drying materials. One of the most popular of the soft brushes is the fitch hair brush made from common American skunk hair. Various types and styles of brushes are shown in Fig. 1.

Care and Cleaning of Brushes—Since brushes represent a considerable investment and may be damaged easily due to improper handling, it is of the utmost importance that proper care be given to the complete assortment of brushes used. Always clean brushes thoroughly with the proper solvent immediately after using them. See that the solvent is worked up into the bristles and into the heel of the brush. Squeeze out as much solvent as possible, repeat the operation two or three times, then give the brush a final rinse in a clean solvent. When a stain or shellac brush has been cleaned and is not to be used again immediately it should be wrapped in heavy paper for protection; other brushes can be kept in special brush containers.

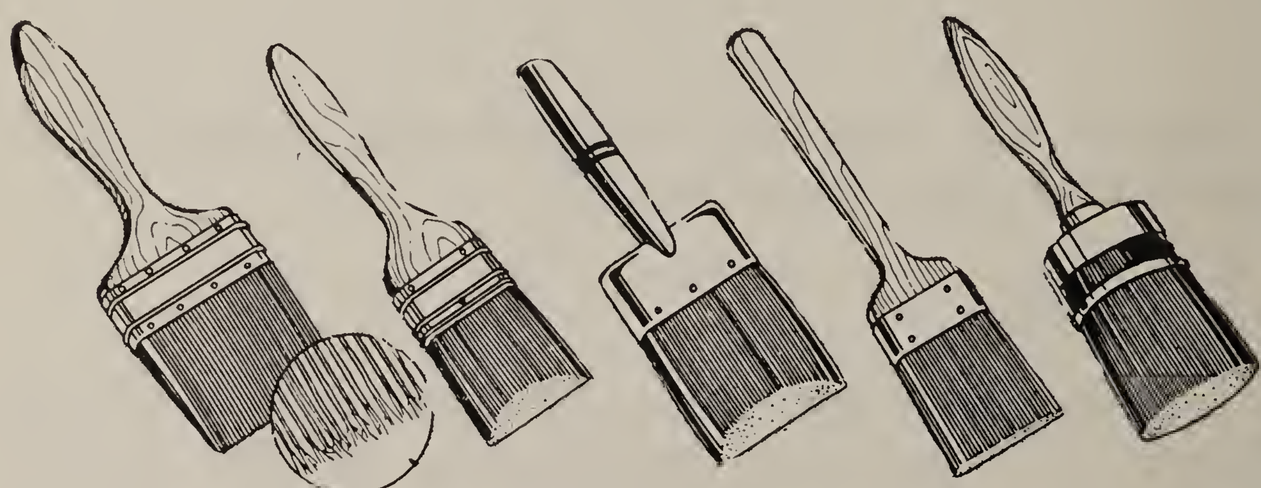


Fig. 1. Miscellaneous paint brushes and cleaning tools. Wire brushes of the type shown are used in cleaning rust from pipes and other steel surfaces prior to application of the paint. Dust brushes, as the name implies, are used for removal of dust before painting, since a clean surface is essential for a good finish.

Brush Containers—Simple brush containers consist essentially of metal or glass containers of suitable size in which brushes can be suspended in the proper liquids in such a manner as to prevent the ends of the bristles from touching the bottom. The fluid level should be maintained so that the bristles are completely submerged.

Brushing Technique—Only common sense and a little practice will indicate the correct use of brushes. On large areas, cross brushing usually insures good coverage and eliminates skipped spots. For general brush work, the bristles should be dipped to about one-third of their length, and surplus paint should be wiped off on the edge of the can. When finishing flat surfaces, brush out

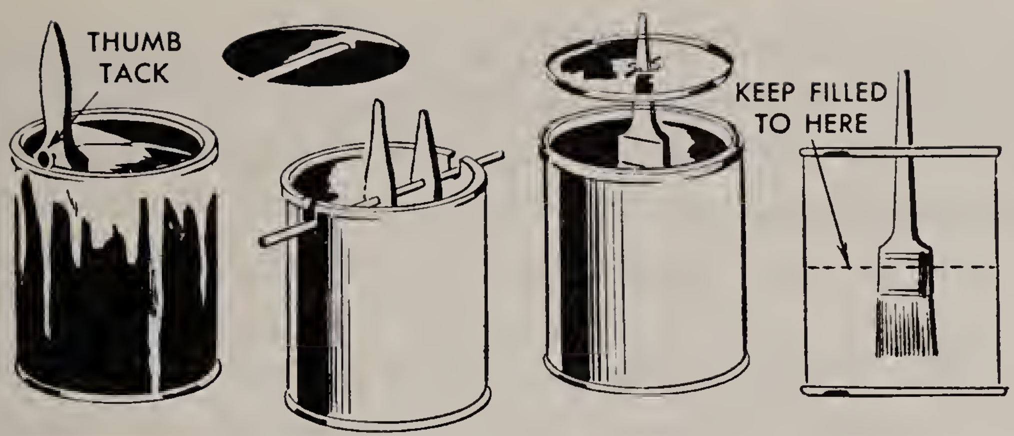


Fig. 2. Typical brush containers showing method of keeping brush bristles submerged in liquid while not in use.

toward the edges in order to prevent drips which usually occur when a loaded brush is pulled over a sharp edge. When brushing stain, shellac, lacquer, and other materials with which a uniform coat must be applied without undue brushing, a great deal of care should be exercised in order not to double coat any part of the work.

SPRAYING EQUIPMENT

Spray equipment used around the home and in the average workshop consists of three items, namely:

1. Air compressor.
2. Gun.
3. Hose.

Air Compressors—There are two kinds of air compressors—the piston and the diaphragm type. The piston type consists of a metal piston working inside a cylinder, very much like the piston in an automobile engine. Thus, on the downward stroke of the piston, air is drawn into the cylinder; on the upward stroke, the air is compressed.

The diaphragm type of compressor differs from the piston type mainly in that it is equipped with a flexible diaphragm instead of the metal piston. Because the diaphragm type of compressor may easily be replaced when worn out, the latter type is usually preferred in spraying applications around the home where the compressed air requirements are small. The motor supplying the power

for the compressor is furnished in a fractional-horsepower size and determines the size of the compressor. For home spraying equipment, ¼- to ⅓-horsepower is the smallest motor practical for satisfactory spraying.

Air Volume and Pressure—The basic requirement for any paint sprayer is an efficient, high-output compressor that supplies the spray gun with a smooth continuous flow of air, permitting the paint to be applied without excessive thinning and providing a smooth even coat which will give maximum protection and wear. To measure the performance of a compressor, the following terms are commonly used:

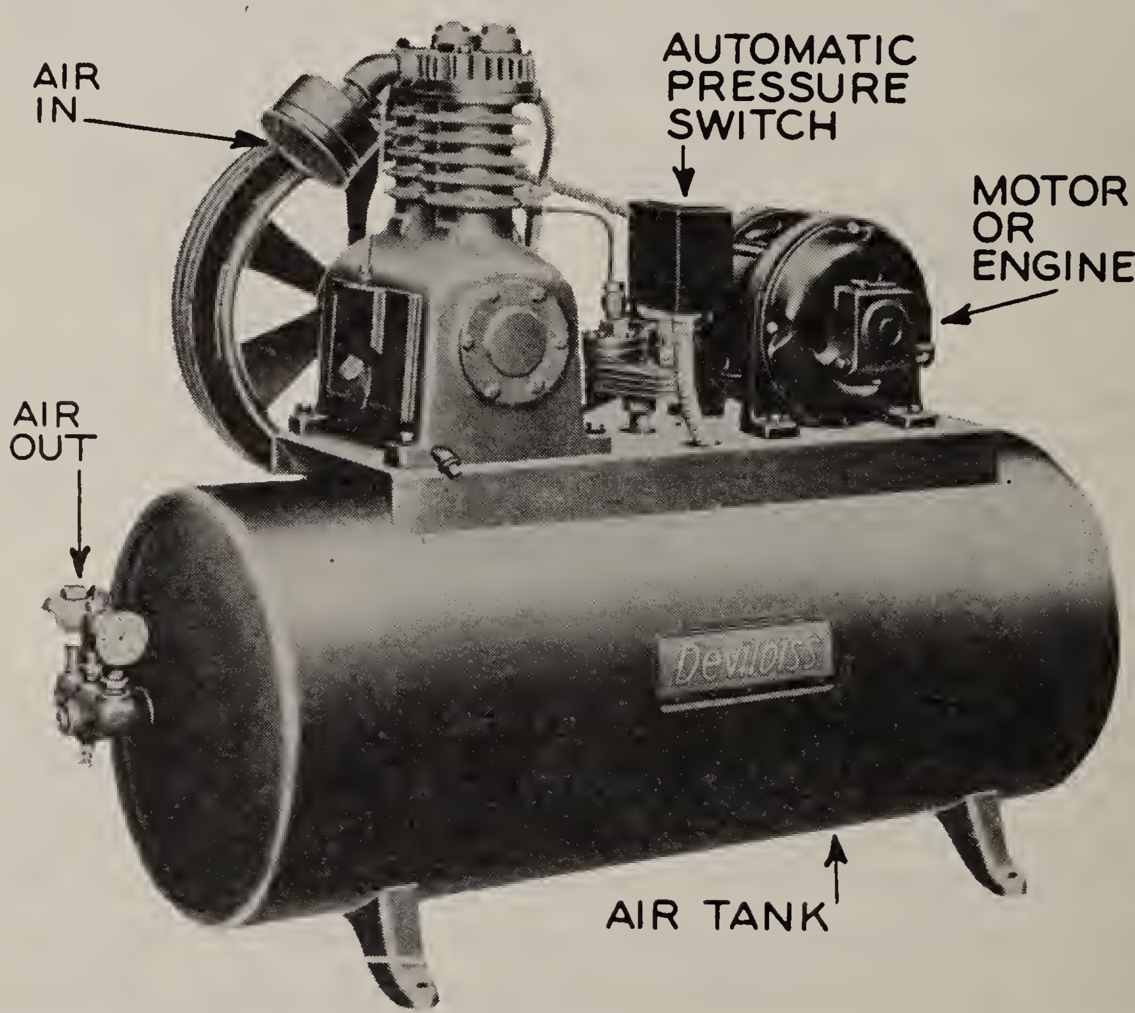


Fig. 3. Stationary piston-type air compressor suitable for paint spraying. An automatic pressure switch keeps the air pressure between 80 and 100 pounds. A tank outfit of this type is suitable for use in paint shops or manufacturing plants where spraying is done in a fixed location.

Air Displacement—This is the theoretical amount of air in cubic feet that the compressor can pump in one minute at working pressure. It is a relatively simple matter to calculate the air

displacement of a compressor if the cylinder diameter, length of stroke and rpm are known. Thus, for example, the area of cylinder multiplied by the length of the stroke and the shaft revolutions per minute equals the displacement volume. The formula for computing it is as follows:

$$\frac{\text{Area of cylinder} \times \text{stroke} \times \text{rpm} \times \text{no. of cylinders}}{1{,}728} = \begin{array}{c}\text{Displacement}\\ \text{in C.F.M.}\end{array}$$

Both cylinder diameter and the stroke measurement in the foregoing formula should be in inches. The formula applies to single-stage compressors but can be used for two-stage units as well, since in two-stage units, the small high-pressure cylinder or cylinders are not computed.

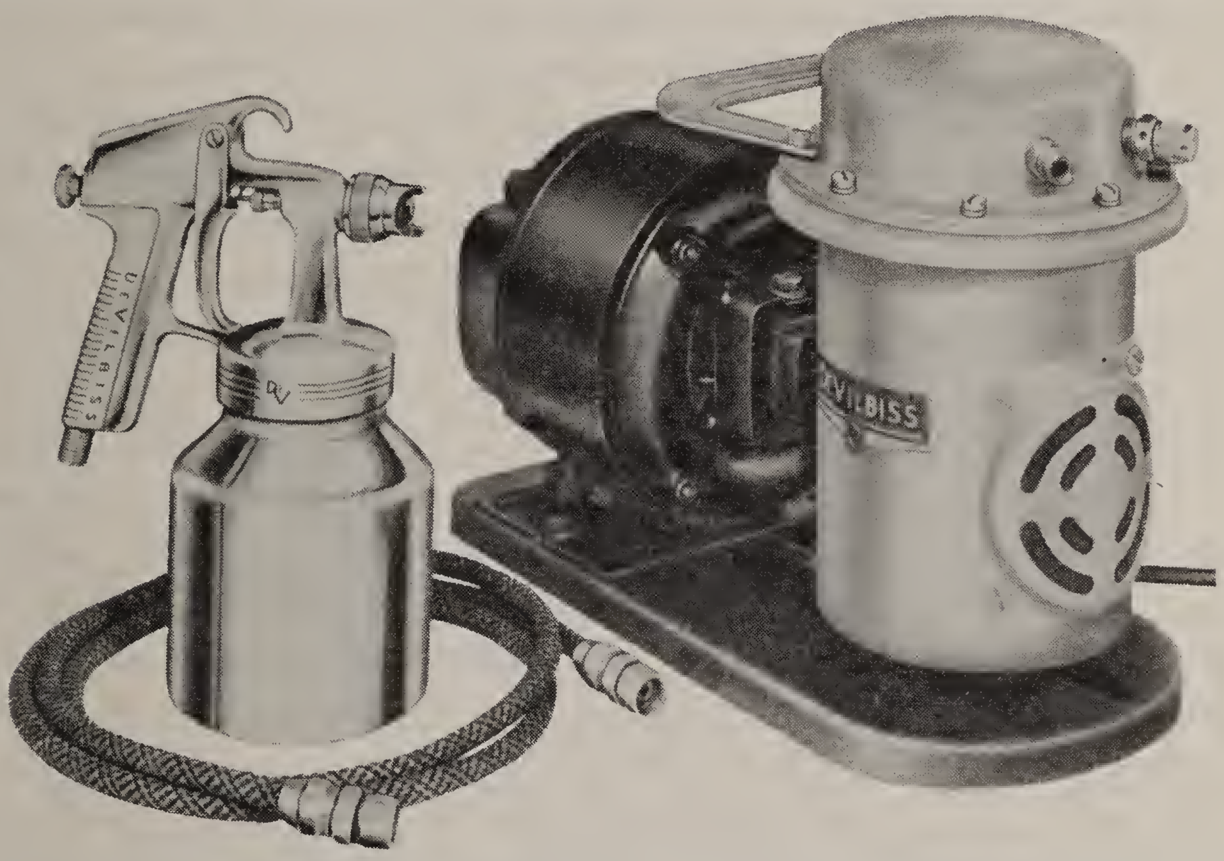


Fig. 4. Typical diaphragm compressor with pressure-feed spray gun and hose for connection between gun and compressor.

Air Delivery—An air compressor is rated on the actual amount of free air pumped in one minute at working pressure for use by the spray gun. Air delivery is always less than the displacement rating, because no compressor is 100 percent efficient. Air delivery at working pressure, not the displacement or the horsepower, is the true rating of the compressor. Thus, for example, a piston or

diaphragm compressor powered with a ⅓-horsepower motor will deliver about 3 cubic feet of free air per minute. Many dealers in paint-spraying equipment never mention air delivery, but feature only terms of air displacement, which, as noted, is the larger figure.

Working Pressure—Working pressure means the number of pounds of pressure a compressor will maintain while in continuous operation with a specific spray gun. Each gun requires a constant air delivery at a certain working pressure for maximum efficiency. Too much air pressure causes over-atomizing and results in a splatter-like finish.

Pressure and Exhaust-Opening Relations—The relationship between the exhaust opening of a spray gun and the air pressure is such that when the size of the exhaust opening is increased, the pressure will decrease and when the opening is reduced, the pressure will increase. This inverse pressure and exhaust-opening relationship may readily be observed if it is noted that an average ⅓-horsepower compressor will deliver about 40 pounds of free air through an exhaust opening of about 1/16-inch diameter; but if the opening is closed, the pressure will immediately jump to about 150 pounds, or more, resulting in motor stoppage due to

Size of Air Hose Inside Diameter	Air Pressure Drop at Spray Gun					
	5-foot length	10-foot length	15-foot length	20-foot length	25-foot length	50-foot length
1/4-inch	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
At 40 lbs. pressure	6	8	9½	11	12¾	24
At 50 lbs. pressure	7½	10	12	14	16	28
At 60 lbs. pressure	9	12½	14½	16¾	19	31
At 70 lbs. pressure	10¾	14½	17	19½	22½	34
At 80 lbs. pressure	12¼	16½	19½	22½	25½	37
At 90 lbs. pressure	14	18¾	22	25¼	29	39½
5/16-inch						
At 40 lbs. pressure	2¼	2¾	3¼	3½	4	8½
At 50 lbs. pressure	3	3½	4	4½	5	10
At 60 lbs. pressure	3¾	4½	5	5½	6	11½
At 70 lbs. pressure	4½	5¼	6	6¾	7¼	13
At 80 lbs. pressure	5½	6¼	7	8	8¾	14½
At 90 lbs. pressure	6½	7½	8½	9½	10½	16

Courtesy DeVilbiss Company

Fig. 5. Table showing air-pressure drops for various sizes of hose at a given distance from the compressor.

operation of the automatic pressure switch or other safety device incorporated in the equipment.

Air Pressure and Air Hose Relations—When pumping the air from the compressor to the gun, a pressure drop is produced. This pressure drop is due to friction between the flowing air and the walls of the hose, pipe line, and passages through which it travels. Too often a spray gun is blamed for improper functioning when the real trouble is an inadequate supply of compressed air at the gun. Operators frequently believe they are using very high pressure but an investigation would reveal that, due to a small hose size or one of excessive length, the pressure is inadequate for proper atomizing. The fact that this pressure drop is an important factor to consider is shown in the table in Fig. 5. The pressure drops shown in the table are based on the air consumption of a spray gun equipped with an air gap drawing approximately 12 cubic feet of air per minute at 60 pounds pressure.

Spray Guns—In operation, the spray gun atomizes the material which is being sprayed. The operator controls the flow of the material with the trigger attachment on the gun. Spray guns are supplied in various sizes of nozzles and air gaps to permit the handling of different types of material. An air adjustment built into the gun makes possible a change in the shape and size of the spray pattern ranging from a wide fan-shaped spray to a small round spray as the occasion requires.

Spray guns are either external mix or internal mix. In the external-mix type of gun, the material leaves the gun through one hole, while the air leaves through another hole. The air hole is positioned so that the air stream blows across the material hole. Spray guns in which the air and material are mixed before leaving the orifice of the gun are of the internal-mix type.

The *suction-feed gun*, as the name implies, siphons the material from a cup attached to the gun and is generally used for radiators, grills, and other small projects which require light-bodied material in small amounts. The *pressure-feed gun* forces the material from the container by air pressure. Air directed into the container puts the material under pressure and forces it to the nozzle. The pressure-type gun is undoubtedly the best all-round gun for use with small compressors and with such materials as house paint, floor enamels, wall paints, and the like.

A spray gun is either a bleeder or nonbleeder type. A bleeder type is one which is designed for passage of air at all times, whereas a nonbleeder gun cannot pass air until the trigger is pulled. This latter type of gun is used only when air is supplied from a tank or from a compressor equipped with pressure control. Bleeder guns are always used when working directly from small compressors such as are used in small workshops or for spraying jobs around the home.

Spraying Equipment Connections—There are several possible hookups for various types of applications. The simplest possible hookup is one where the feed is directly from the compressor to the gun as shown in Fig. 6. A connection from the compressor to the fluid tank to the pressure-feed gun is also shown in Fig. 6. This is a preferred method on large paint jobs. Any of the four hookups can also be used with air supplied from a tank.

Accessories—One of the most useful accessories for home spraying is the angle head. An angle head fitted to the pressure gun prevents excessive tilting of the fluid cup when spraying floors, ceilings and similar surfaces. A respirator is seldom required for

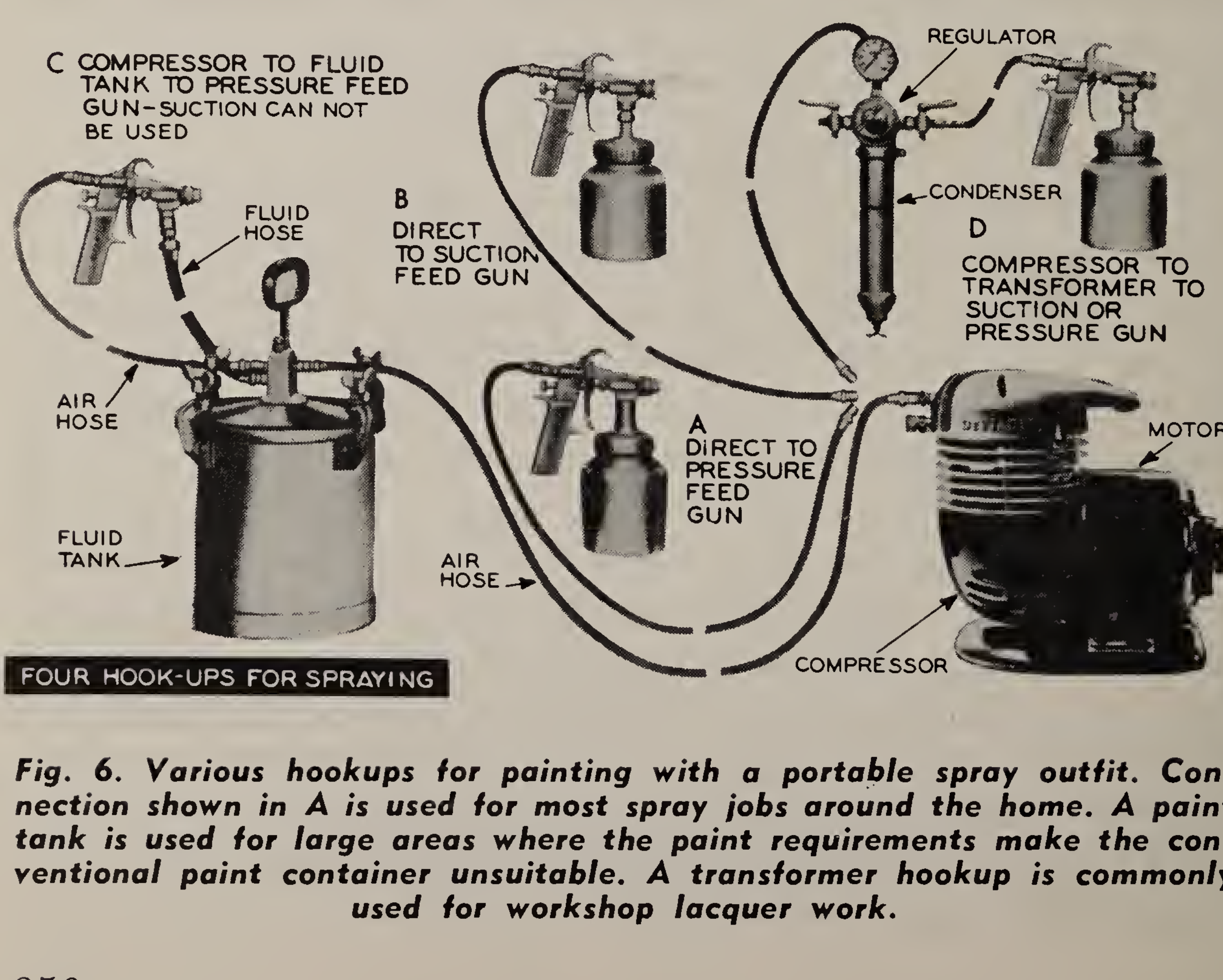


Fig. 6. Various hookups for painting with a portable spray outfit. Connection shown in A is used for most spray jobs around the home. A paint tank is used for large areas where the paint requirements make the conventional paint container unsuitable. A transformer hookup is commonly used for workshop lacquer work.

work of short duration, but it is a very useful item when spraying for long periods in confined quarters.

Another useful accessory is the condenser which filters water, oil, and various foreign particles out of the air supply. If the condenser is fitted with an air regulator, the combination is termed a transformer. Thus, with a condenser-regulator combination, it it possible to have the air filtered while the regulator allows setting the air pressure at a predetermined rate as required for the particular job. Additional useful accessories consist of an air-duster gun and extra lengths of air hose with couplings to allow an increase in the working radius.

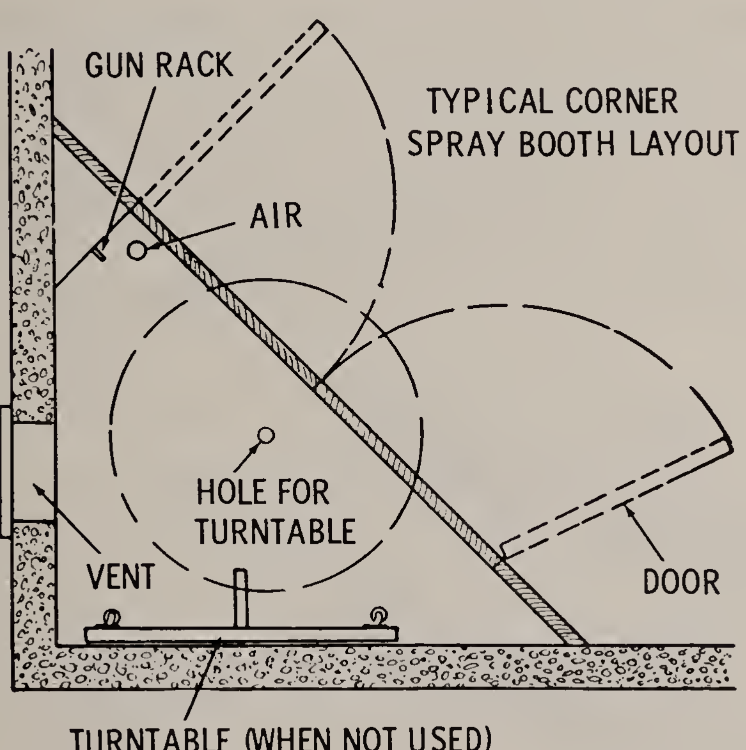


Fig. 7. Typical corner spray booth suitable for the average home workshop. Since the space requirement depends upon the size of articles to be sprayed as well as the frequency of use, no recommendation as to floor area and cubic content are given. An exhaust fan properly installed in the vent opening or exhaust stack is recommended for removing fumes from the work area. Cleaning of the booth should be regularly scheduled so that fire hazards are reduced and the full efficiency of the system maintained.

Spray Booths—Where spray equipment is installed in a permanent location and the work to be sprayed is of such size that it can be conveniently done in one place, exhaust-equipped spray booths are usually provided for the removal of vaporized paint and odors. Spray booths are made in various sizes and types for specific purposes, ranging from a simple frame and plywood or

sheet-metal enclosure to well-equipped, commercial-type, water-wash booths used in production plants.

The ordinary floor-type booth may accumulate a certain amount of waste material after the spraying has been completed. This should be removed immediately because cleanliness is important to good spray results. When spraying in confined areas it is advisable to have a portable fan secured in a frame which can be placed in a window to provide proper ventilation. Turntables of simple construction are used in spray booths to facilitate rotation of work while spraying. A suitable turntable eliminates a lot of body movement as well as handling of the work during the spraying process.

Placing the Work—Prior to the actual spraying it is necessary to arrange the work properly, and one of the fundamental rules relating to placement is to get the work off the floor. There are several methods to accomplish this, the most common of which is to provide a pair of sawhorses bridged with suitable boards or planking. Another way to get the work off the floor and in a com-

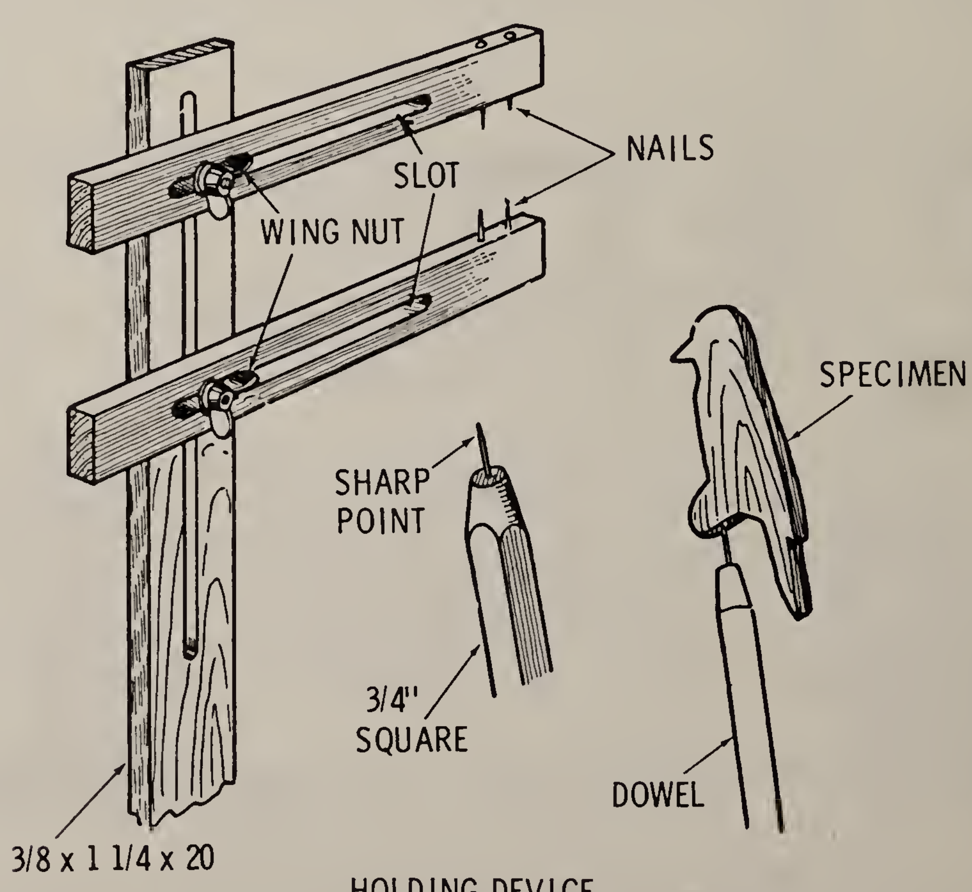


Fig. 8. Holding device for spraying small articles of wood or other light material. The article to be sprayed may be held between the projecting nails in a suitable stand or speared to the end of a wooden rod as illustrated.

fortable spraying position is to suspend the work with rope or hooks from a clothesline or other convenient overhead support. The suspension method offers maximum convenience in manipulating objects that are without a base.

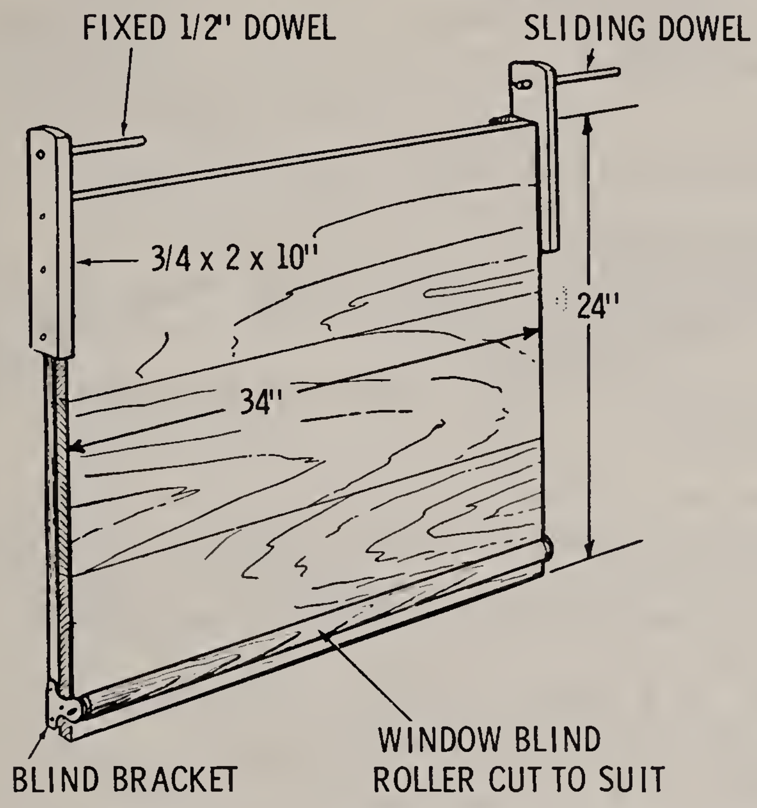


Fig. 9. Typical backstop stand suitable for spray pattern tests or as a backstop when spraying small and medium-sized articles.

Small wood articles can be readily sprayed if speared on an icepick or special holding device, such as illustrated in Fig. 8. For general indoor spraying, an adjustable backstop stand such as shown in Fig. 9 will prove very satisfactory. This stand uses newspaper and provides a suitable surface for testing of the spray gun as well as a backstop when spraying the work. Other practical support and work-holding devices may be improvised to suit almost any condition and space requirement. Large articles of wood or metal are sometimes suspended by a block-and-tackle arrangement, permitting the work to be hoisted out of the way for drying after spraying.

Spraying Technique—Prior to commencing the actual spraying job, it is good practice to test spray a few panels in order to get the feel of the gun and to make any necessary adjustments. Such practice spraying can be done on old cartons or on sheets of news-

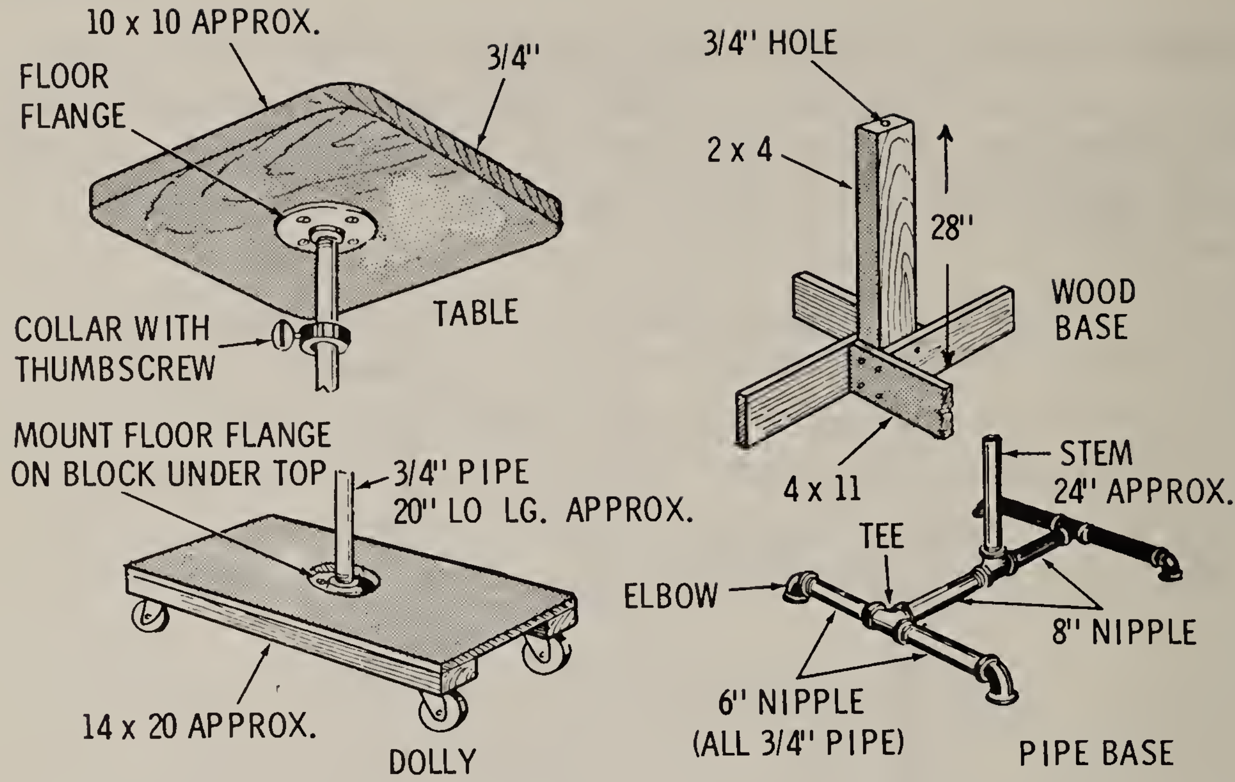


Fig. 10. Pedestal turntable with height adjustment for placement of small furniture and similar articles to be sprayed. Various base styles may be used to suit individual preferences.

paper tacked to a carton or box. With the cup filled with water-mixed paint or other inexpensive material, practice spraying can be done directly on any odd material as previously noted. It will be useful to experiment with the full range of fluid adjustment, starting with the needle screw backed off from the closed position just far enough to obtain a small pattern an inch or so wide when the trigger is pulled all the way back.

With this small pattern, the stroke and triggering effect should be practiced. After getting the feel of the gun, gradually back off

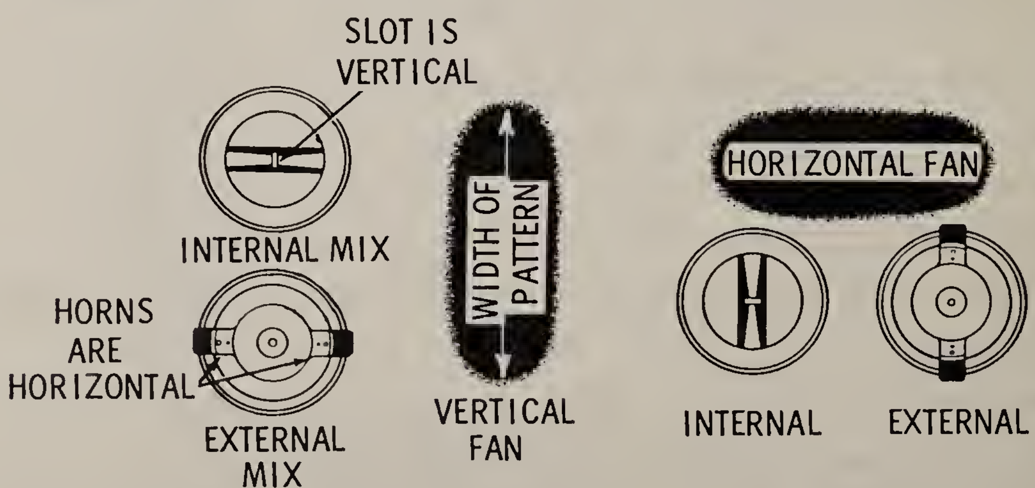


Fig. 11. Cap position determines pattern direction in internal- and external-mix types of guns respectively.

the needle screw to spray more material and widen the pattern. With the increased flow of material through the gun, it may be found that the breakup or atomization becomes coarser. A pattern about 6 to 8 inches wide when the gun is held 6 to 8 inches from the surface is the practical size for wall painting. Test patterns should be sprayed in both vertical and horizontal position, the required adjustment for pattern direction being made by rotating the nozzle or air gap, as illustrated in Fig. 11.

The spray-gun stroke is made by moving the gun parallel to the work and at right angles to the surface. The speed of stroking should be about the same as brushing. The distance from gun to work should be between 6 and 8 inches. Practice should be done with straight uniform strokes moving back and forth across the surface in such a way that the pattern laps about 50 percent on each pass. An appreciable variation of distance between gun and work or angle of the gun will result in uneven coatings. Therefore, always hold the gun without tilting and move it correctly. Spraying is merely the action of the wrist and forearm and the proper technique is readily and easily acquired. Fairly large pieces of scrap wood remaining from the project are excellent for practicing spray

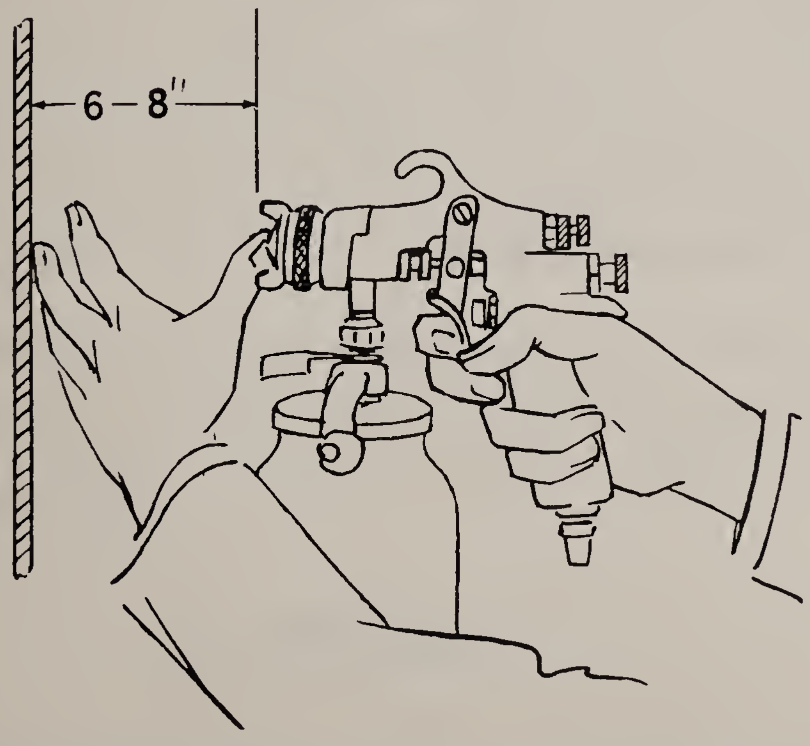


Fig. 12. Method of measuring distance from gun tip to work when spraying. As noted in the illustration, gun distance from work will average about six inches but is subject to some variation depending upon the kind of paint and the nature of the work.

patterns, because this gives the operator an idea of any problems he might expect in actually spraying the final project itself.

Release the trigger at the end of each stroke to avoid piling up material. Avoid pivoting or circular movements of the wrist or forearm or any oblique spraying which will cause material to rebound from the surface. It causes excessive mist and waste material as well as a patchy, unsatisfactory job.

Cleaning the Gun—To obtain continued and satisfactory service, a spray gun like any other tool requires constant care. It should not be left in a thinner overnight, because such practice removes the lubricant from the packing through which the needle moves thereby causing the needle to stick and the gun to "spit." A dirty air gap causes a defective spray, so it is good practice to clean it promptly after the spraying job is finished. At the end of the day remove the gun from the cup and hose and thoroughly clean it. Clean the entire gun, the outside as well as the inside. The cup or tank should likewise be cleaned.

CHAPTER 22

Practical Shop Mathematics

Two thousand years ago, Hindu scholars invented and gave to the world the ten symbols which are now used by mathematicians all over the world—0, 1, 2, 3, 4, 5, 6, 7, 8, 9—and with only these ten symbols and the place system, we can express any number no matter how great or small. Later, in the tenth century, Arabian philosophers who had learned to use these symbols brought them to Europe in substantially the same form we know them, and we still call them the Arabic notation. Since in those days all writing was done by hand, the actual forms varied somewhat, and not until the invention of the printing press in the fifteenth century were the forms of the numerals fixed in the type styles we are familiar with and which are today used all over the civilized world.

Most carpenters and builders have a fairly good basic knowledge of the uses of numbers, and we will not dwell too long on fundamental principles, but many examples which are useful to carpenters will be given.

ARITHMETIC

Definitions

1. *Arithmetic* is the art of calculating by using numbers. All of the sciences are based on arithmetic and the ability to

use it. In fact, it has been said that we do not have a true science until we can number. To paraphrase that statement, we can say that we do not have a good carpenter until he understands numbers thoroughly and knows how to use them properly.

2. A *number* is a total, amount, or aggregate of units. By counting the units, we arrive at a certain number, as *two* horses, *five* dozen, etc.
3. A *unit* may mean a single article, but often it means a definite group which is adopted as a standard of measurement, such as *dozen, ton, foot, bushel,* or *mile.* Most commonly used units are standardized, and their magnitude is defined and fixed by law.
4. A *concrete* number is a number applied to some particular unit, such as *ten* nails, *two* dozen eggs, *six* miles.
5. An *abstract number* is one that is *not* applied to any object or group, such as simply *two, four, ten.*
6. *Notation* is the art of expressing numbers by figures or letters. Our system of notation is the Arabic notation. The Roman notation uses letters, such as V = 5, X = 10, etc.
7. *Cardinal numbers* are numbers used in simple counting or in reply to the question "How many?" Any number may be a cardinal number.
8. *Ordinal numbers* indicate succession or order of arrangement, such as *first, second, tenth,* etc.
9. An *integer,* or *integral number,* is a whole number, not a fraction or part.
10. An *even number* is any number which can be exactly divided by 2, such as 4, 16, 96, 102.
11. An *odd number* is any number which is *not* exactly divisible by 2, such as 3, 15, 49, 103.
12. A *factor* of a number is a whole number which may be exactly divided into the number. For example, 3 is a factor of 27, 13 is a factor of 91.
13. A *prime number* is a number which has no factors other than itself and 1. Thus, 3, 5, 7, and 23 are prime numbers.
14. A *composite number* is a number which has factors other than itself and 1, such as 8, 49, and 100.
15. A *multiple* of a number is a number which is exactly di-

visible by a given number. For example, 91 is a multiple of 7, 12 is a multiple of 3.

16. A *digit* is any number from 1 to 9, and usually 0.

Signs of Operation

1. The *sign of addition* is $+$, and it is read "plus" or "add." Thus, $7 + 3$ is read "seven plus three." The numbers may be taken in *any order* when adding; $7 + 3$ is the same as $3 + 7$.
2. The *sign of subtraction* is $-$, and it is read "minus." A series of subtractions *must* be taken in the order written—$11 - 7$ is *not* the same as $7 - 11$.
3. The *sign of multiplication* is $\times$, and it is read "times" or "multiplied by." The numbers may be taken in *any order* when multiplying; 4×7 is the same as 7×4.
4. The sign of division is $\div$, and it is read "divided by." A series of divisions *must* be taken in the order written—$(100 \div 2) \div 10 = 5$.
5. The *sign of equality* is $=$, and it is read "equals" or "is equal to." The expressions on each side of an equality sign must be numerically the same. The complete expression is called an *equation*.

Rules for Finding Divisors of Numbers

Sometimes useless labor can be avoided by making a check of divisibility using one of the following rules.

1. A number is divisible by 2 if its right-hand digit is 0 or one which is divisible by 2. Thus, 62, 114, 1078 are all divisible by 2.
2. A number is divisible by 3 if the sum of its digits is divisible by 3. Therefore, 27, 72, 201 are all divisible by 3.
3. A number is divisible by 4 if the number represented by the last two digits on its right are divisible by 4. For example, 2772 is divisible by 4 since 72 is divisible by 4.
4. A number is divisible by 5 if the last digit on its right is 0 or 5. Thus, 105, 255, and 1005 are all divisible by 5.
5. An even number the sum of whose digits is divisible by 3 is divisible by 6. For example, 2028 is divisible by 6, but the number 327,273 is not.

6. There is no quick check for divisibility by 7; it is necessary to make a trial.
7. A number is divisible by 8 if the last 3 digits on the right of that number are divisible by 8. Therefore, the number 967,568 is divisible by 8 because 568 is divisible by 8.
8. A number is divisible by 9 if the sum of its digits is divisible by 9. Thus, the number 7,642,764 is divisible by 9 since the sum of its digits, 36, is divisible by 9.

How the Signs of Operation Are Used

Example—*The use of the sign of addition.* A builder when building a house buys 1762 board feet of lumber from one yard, 2176 board feet from another, and 276 board feet from another. How many board feet did he buy?

The problem: $1762 + 2176 + 276 = ?$

The solution:
$$\begin{array}{r} 1762 \\ 2176 \\ +276 \\ \hline 4214 \end{array} \text{ board feet}$$

Note how the numbers are aligned to permit addition. The units are all aligned on the right, then the tens, then the hundreds, then the thousands, each in the proper column.

Example—*The use of the sign of subtraction.* A carpenter bought 300 lb. of nails for a job, and he had 28 lb. left when he finished. How many pounds of nails did he use to complete the job?

The problem: $300 - 28 = ?$

The solution:
$$\begin{array}{r} 300 \\ -28 \\ \hline 272 \end{array} \text{ pounds}$$

Note that the numbers must be aligned as they were for addition.

Example—*The use of the sign of division.* A man's car gets an average of 17 miles per gallon of gasoline. How many gallons of gasoline would be required for him to travel 2040 miles in his car.

The problem: $2040 \div 17 = ?$

The solution:

$$\begin{array}{r}
120 \\
17\,\overline{)2040} \\
17 \\
\hline
34 \\
34 \\
\hline
00
\end{array}$$

Example—*The use of the sign of equality.* A road contractor finds that he can lay the same amount of paving in 12 days using a 6-man crew that he can lay in 8 days using a 9-man crew. Express this statement as an equation.

$$12 \times 6 = 9 \times 8, \text{ or } 72 = 72$$

Roman Numerals

The Roman notation (Table 1) is still occasionally used for highly formalized inscriptions, such as the dates on cornerstones of buildings, on college diplomas, years of copyright in books, numbers of chapters and sections in books, etc.

Table 1. Arabic and Roman Notations

0 = O	11 = XI
1 = I	12 = XII
2 = II	13 = XIII
3 = III	14 = XIV
4 = IV	15 = XV
5 = V	16 = XVI
6 = VI	17 = XVII
7 = VII	18 = XVIII
8 = VIII	19 = XIX
9 = IX	20 = XX
10 = X	21 = XXI

22	= XXII	101	= CI
23	= XXIII	102	= CII
24	= XXIV	103	= CIII
25	= XXV	104	= CIV
26	= XXVI	150	= CL
27	= XXVII	200	= CC
28	= XXVIII	300	= CCC
29	= XXIX	400	= CD
30	= XXX	500	= D
31	= XXXI	600	= DC
32	= XXXII	700	= DCC
40	= XL	800	= DCCC
50	= L	900	= CM
60	= LX	1000	= M
70	= LXX	2000	= MM
80	= LXXX	10,000	= $\overline{\text{X}}$
90	= XC	100,000	= $\overline{\text{C}}$
100	= C	1,000,000	= $\overline{\text{M}}$

Fractions

A fraction indicates that a number or a unit has been divided into a certain number of equal parts, and shows how many of these parts are to be considered. Two forms of fractions are in common usage—the decimal, which is expressed in the tenths system, and the common fraction. The common fraction is written by using two numbers, one written over the other with a line between them. The lower number, called the *denominator,* indicates the number of parts into which the unit has been divided, and the upper number, called the *numerator,* indicates the number of parts to be considered. In the fraction 2/3, the lower number shows that the unit is divided into 3 parts; the upper number indicates that 2 parts are being considered.

If the quantity indicated by the fraction is less than 1, such as 1/2, 3/4, or 5/6, it is called a *proper fraction.* If the quantity indicated by the fraction is equal to or greater than 1, such as 3/3, 5/4, or 7/6, it is called an *improper fraction.* When a whole number and a proper fraction are combined, such as 2-1/4, 6-1/2, etc., it is called a *mixed number.*

Addition of Fractions—Fractions cannot be added without first reducing them to a common denominator.

Example—Add 3/4 + 2/9 + 2/3 + 7/12

To find the common denominator, place the denominators in a row, separated by dashes. Divide them by a prime number which will divide into at least two of them without leaving a remainder, and bring down the denominators with the dividends which did not contain the divisor without a remainder. Repeat this process as often as possible until there are no two numbers remaining which can be divided by the same number. Then, multiply the divisors and the remainders together, and the result will be the smallest common denominator.

The solution:

$$\begin{array}{r|l} 2 & \underline{4\text{-}9\text{-}3\text{-}12} \\ 3 & \underline{2\text{-}9\text{-}3\text{-}6} \\ 2 & \underline{2\text{-}3\text{-}1\text{-}2} \\ & 1\text{-}3\text{-}1\text{-}1 \end{array}$$

The common denominator will then be $2 \times 3 \times 2 \times 3 = 36$. The fractions are then reduced to the common denominator of 36 by multiplying the numerator and the denominator by the same number which will produce 36 in the denominator, as:

$$3/4 = 3/4 \times 9/9 = 27/36$$

$$2/9 = 2/9 \times 4/4 = 8/36$$

$$2/3 = 2/3 \times 12/12 = 24/36$$

$$7/12 = 7/12 \times 3/3 = 21/36$$

$$\text{The sum of the fractions} = \frac{27 + 8 + 24 + 21}{36} = 80/36 \text{ or } 20/9$$

Multiplication of Common Fractions—A fraction may be multiplied by a whole number by multiplying the numerator of the fraction by that number.

Example—If 3/4 of a keg of nails is used for siding a garage, how many kegs of nails will be used when siding 8 similar garages?

The solution: $8 \times 3/4 = 24/4$

A fraction may be simplified by dividing both the numerator and the denominator by the same number, and its value will not be affected.

Example—Divide both the numerator and the denominator of the improper fraction 24/4 by 4.

The result will be 6/1, or 6. Therefore, 6 kegs of nails will be required to put the siding on the 8 garages.

Fractions may be multiplied by fractions by multiplying their numerators together and their denominators together.

Example—Multiply

$$2/5 \times 1/4 \times 5/12 = \frac{2 \times 1 \times 5}{5 \times 4 \times 12} = \frac{10}{240} = \frac{1}{24}$$

Multiplication of Fractions by Cancellation—This may readily be done, because any factor below the line may be divided by any factor above the line, and any factor above the line may be divided by any factor below the line, without altering the overall value of the expression. Take the example $12/30 \times 14/56 \times 10/24$ and write it in this form:

$$\frac{\overset{1}{\cancel{12}} \times \overset{1}{\cancel{14}} \times \overset{1}{\cancel{10}}}{\underset{3}{\cancel{30}} \times \underset{4}{\cancel{56}} \times \underset{2}{\cancel{24}}}$$

The 30 below the line may be divided by the 10 above the line—result, 3. The 56 below the line may be divided by the 14 above the line—result, 4. The 24 below the line may be divided by the 12 above the line—result, 2. The result of the cancellation, then, is

$$\frac{1}{3 \times 4 \times 2} = \frac{1}{24}$$

Division of Fractions—Fractions may be divided by whole numbers by dividing the numerator by that number or by multiplying the denominator by that number.

Example

$$\frac{7}{8} \div 7 = \frac{1}{8}$$

$$\frac{7}{8} \div 7 = \frac{7}{56} = \frac{1}{8}$$

Fractions may be divided by fractions by inverting the divisor and multiplying.

Example

$$\frac{7}{8} \div \frac{2}{7} = \frac{7}{8} \times \frac{7}{2} = \frac{49}{16}$$

which is the mixed number 3-1/16.

Subtraction of Fractions—Fractions cannot be subtracted from fractions without first reducing them to a common denominator, as is done for the addition of fractions.

Example—Subtract $\frac{13}{16}$ from $\frac{5}{6}$

Finding the least common denominator,

$$2\ \underline{)\ 16 - 6}\qquad 2 \times 8 \times 3 = 48$$
$$\quad 8 - 3$$

$$\frac{13}{16} = \frac{13}{16} \times \frac{3}{3} = \frac{39}{48}$$

$$\frac{5}{6} = \frac{5}{6} \times \frac{8}{8} = \frac{40}{48}$$

$$\frac{40 - 39}{48} = \frac{1}{48}$$

To subtract a mixed number from another mixed number, it is usually most convenient to reduce both numbers to improper fractions and then proceed as shown in the last example.

To subtract a mixed number from a whole number, borrow 1 from the minuend, or upper number; reduce the 1 to an improper denominator of the fraction in the subtrahend, or lower number, thereby reducing the whole number by 1. Then make the subtraction in the normal manner.

Example—Subtract 6 7/8 from 14.

The solution: $14 - 6\ 7/8 = 13\ 8/8 - 6\ 7/8 = 7\ 1/8$

Applications of Cancellation—There are numberless applications where this method will save appreciable time and work, but care and thought must be given to the proper arrangement of the fractional expression if there are many factors. Also, it must be remembered that if addition or subtraction signs appear, cancellation *may not* be used.

Example–A circular saw has 75 teeth with a 1-inch spacing between each tooth. In order to do satisfactory work, the rim of the saw should travel at approximately 9000 feet per minute. How many revolutions should this saw make per minute? (Hint: 75 inches $= \frac{75}{12}$ feet.)

The solution:

$$\frac{\overset{120}{9\cancel{000}} \times 12}{\cancel{75}} = 120 \times 12 = 1440 \text{ rev. per min.}$$

Example—If you go to a bank and borrow $1000 to purchase a car, how much will the interest be, at 6% per annum, on the money you borrow for 1 year and 3 months? (Hint: 1 year 3 months = 15 months.)

The solution:

$$\frac{\cancel{6} \times \overset{\overset{5}{\cancel{10}}}{\cancel{1000}} \times 15}{\cancel{100} \times \underset{2}{\cancel{12}}} = 5 \times 15 = \$75$$

Example—If 8 men in fifteen 8-hour days can throw 1000 cubic yards of gravel into wheelbarrows, how many men will be required to throw 2000 cubic yards of gravel into wheelbarrows in twenty days of 6 hours each?

The solution:

$$\frac{\overset{3}{\cancel{15}} \times \overset{2}{\cancel{8}} \times \overset{4}{\cancel{8}} \times \overset{2}{\cancel{2000}}}{\underset{4}{\cancel{20}} \times \underset{2}{\cancel{6}} \times \cancel{1000}} = 2 \times 4 \times 2 = 16 \text{ men}$$

Example—A building which is 30′ x 30′ with a 10-foot ceiling contains approximately 700 pounds of air. What will be the weight of the air in a room 120 feet long, 90 feet wide, and 16 feet high?

The solution:

$$\frac{\overset{4}{\cancel{120}} \times \overset{3}{\cancel{90}} \times 16 \times \overset{70}{\cancel{700}}}{\cancel{30} \times \cancel{30} \times \cancel{10}} = 4 \times 3 \times 16 \times 70 = 13{,}440 \text{ pounds}$$

Decimals

Decimal means numbering which proceeds by *tens,* and decimal fractions, usually simply called *decimals,* are formed when a unit is divided into 10 parts. When decimals are written, the point where the numeration starts is called the *decimal point.* To the left of the decimal point, the numeration reads in the regular manner—units, tens, hundreds, thousands, ten thousands, hundred thousands, millions, etc. To the right of the decimal point, the figures are fractional, reading, from the point, tenths, hundredths, thousandths, ten thousandths, hundred thousandths, millionths, etc.

The common fraction 6/10 can be expressed decimally as .6, and the fraction 105/1000 can be written as .105. The mixed

number 106 6/100 may be expressed decimally as 106.06. The decimal .6 is read "six tenths," the same as the common fraction 6/10, and the decimal 106.06 is read "one hundred six *and* six hundredths," the same as the mixed number.

It is not necessary to place a zero before the decimal point, as 0.06, but it is sometimes convenient when it is necessary to align a column of decimals for addition. The decimal points must *always* be aligned for addition, as shown in the following example.

$$
\begin{array}{r}
.6 \\
6.29 \\
+\,10.72 \\
\hline
17.61
\end{array}
$$

The position of the decimal point in the sum is established directly under the column of decimal points above the line. *Note*: the number 327 is *not* read "three hundred *and* twenty-seven," but "three hundred twenty-seven"; however, the decimal 300.27 is read "three hundred *and* twenty-seven thousandths." The decimal .327 is read "three hundred twenty-seven thousandths," while the decimal 300.027 is read "three hundred *and* twenty-seven thousandths."

Reduction of Common Fractions to Decimals—Divide the numerator by the denominator, adding zeros and carrying the division to as many decimal place as are necessary or desirable. See Table 2 on pages 25 and 26.

Example—Reduce the common fraction 21/32 to a decimal.

$$
\begin{array}{r@{\,}l}
 & .65625 \\
32 & \overline{)21.00000} \\
 & \underline{19\,2} \\
 & 1\,80 \\
 & \underline{1\,60} \\
 & 200 \\
 & \underline{192} \\
 & 80 \\
 & \underline{64} \\
 & 160 \\
 & \underline{160} \\
 & 00
\end{array}
$$

Count off as many decimal places in the quotient as those in the dividend *exceed* those in the divisor. The quotient is .65625.

Subtraction of Decimals—Align the decimal points in the minuend and the subtrahend as shown for addition, and proceed as explained in subtraction of whole numbers. The decimal point in the remainder is placed in exact alignment with those decimal points above the line.

Example—Subtract 27.267 from 167.02.

The solution:

$$\begin{array}{r} 167.020 \\ -27.267 \\ \hline 139.753 \end{array}$$

Note that it is necessary to add a zero to the decimal 167.02, in order to make the subtraction, but this does not change its value — $\frac{20}{1000}$ is the same in value as $\frac{2}{100}$.

Multiplication of Decimals—Proceed as in multiplication of whole numbers, and count off as many decimal places in the product as there are in *both* the multiplier and multiplicand.

Example—Multiply 1.76 by .06.

The solution:

$$\begin{array}{r} 1.76 \\ \times .06 \\ \hline .1056 \end{array}$$

Compound Numbers

A compound number expresses units of two or more denominations of the same kind, such as 5 yards, 1 foot, and 4 inches. The process of changing the denomination in which a quantity is ex-

pressed without changing its value is called reduction. Thus, 1 yard and 2 inches = 38 inches, 25 inches = 2 feet and 1 inch, etc., are examples of reduction. Problems of reduction occur and are explained with the various measures and weights.

Reduction Descending—To reduce a compound number to a lower denomination, multiply the largest units in the given number by the number of units in the next lower denomination, and add to the product the units of that denomination in the given number. Continue this process until the original number is reduced as far as desired. For an explanation of this rule, see the following example.

Example—Reduce the quantity 6 yards, 2 feet, 7 inches to inches.

	6	yards
Multiply.....	×3	
	18	feet
Add.......	+ 2	
	20	feet
Multiply.....	×12	
	240	inches
Add.......	+ 7	
Total..........	247	inches

Reduction Ascending—To reduce a number of small units to units of larger denominations, divide the number by the number of units in a unit of the next higher denomination. The quotient is in the higher denomination and the remainder, if any, is in the lower. Continue this process until the number is reduced as far as is desired.

Example—Reduce 378 inches to a quantity of yards, feet, and inches.

The solution:

12) 378
3)31 feet, 6 inches remainder
10 yards, 1 foot remainder

Therefore, 378 inches = 10 yards, 1 foot, 6 inches.

Ratio

By definition, a ratio is the relation of one number to another as obtained by dividing the first number by the second. Thus, the ratio of 2 to 4 is expressed as 2 : 4; the symbol : is read "to" in the case of a ratio and "is to" in the case of a proportion. It is equivalent to "divided by," hence:

$$2 : 4 = 1/2$$

The first term of a ratio is the *antecedent,* and the second term is the *consequent*, thus:

$$\begin{array}{ccc} \text{antecedent} & & \text{consequent} \\ 2 & : & 4 \end{array}$$

Since a ratio is essentially a fraction, it follows that if both terms are multiplied or divided by the same number, the value of the ratio is not altered. Thus:

$$2 : 4 = 2 \times 2 : 4 \times 2 = 2 \div 2 : 4 \div 2$$

Two quantities of different kinds cannot form the terms of a ratio. Thus, no ratio can exist between \$5 and 1 day, but a ratio can exist between \$5 and \$2 or between 1 day and 10 days.

Proportion

When two ratios are equal, the four terms form a proportion. A proportion is therefore expressed by using the sign = or : : between two ratios, thus:

(expressed) 4 : 8 : : 2 : 4
(read) 4 is to 8 as 2 is to 4

The same proportion is also expressed as follows:

$$4/8 = 2/4$$

Table 2. Fractions of an Inch and Decimal Equivalents

			1/64	.015625
		1/32		.031250
			3/64	.046875
	1/16			.062500
			5/64	.078125
		3/32		.093750
			7/64	.109375
1/8				.125000
			9/64	.140625
		5/32		.156250
			11/64	.171875
	3/16			.187500
			13/64	.203125
		7/32		.218750
			15/64	.234375
1/4				.250000
			17/64	.265625
		9/32		.281250
			19/64	.296875
	5/16			.312500
			21/64	.328125
		11/32		.343750
			23/64	.359375
3/8				.375000
			25/64	.390625
		13/32		.406250
			27/64	.421875
	7/16			.437500
			29/64	.453125
		15/32		.468750
			31/64	.484375
1/2				.500000
			33/64	.515625
		17/32		.531250
			35/64	.546875
	9/16			.562500
			37/64	.578125
		19/32		.593750
			39/64	.609375
5/8				.625000
			41/64	.640625

Table 2. Fractions of an Inch & Decimal Equivalents (Cont'd)

		21/32		.656250
			43/64	.671875
	11/16			.687500
			45/64	.703125
		23/32		.718750
			47/64	.734375
3/4				.750000
			49/64	.765625
		25/32		.781250
			51/64	.796875
	13/16			.812500
			53/64	.828125
		27/32		.843750
			55/64	.859375
7/8				.875000
			57/64	.890625
		29/32		.906250
			59/64	.921875
	15/16			.937500
			61/64	.953125
		31/32		.968750
			63/64	.984375
				1.000000

The first and last terms of a proportion are called the *extremes*, and the middle terms are called the *means*, thus:

$$4 : 8 :: 2 : 4$$

The product of the extremes equals the product of the means. Thus, in proportion

$$4 : 8 = 2 : 4$$
$$4 \times 4 = 8 \times 2$$

Since the equation is not altered by dividing both sides by the same number, the value of any term can be obtained as follows:

$$\frac{4 \times 4}{4} = \frac{8 \times 2}{4}$$

$$4 = 2 \times 2 = 4$$

"Rule of Three"

When three terms of a proportion are given, the method of finding the fourth term is called the "rule of three."

Example—If 5 bundles of shingles cost $16, what will 25 bundles cost?

Let X represent the unknown term in the proportion, and, remembering that each ratio must be made up of like quantities,

$$5 \text{ bundles} : 25 \text{ bundles} = 16\ (\$) : X\ (\$)$$

Multiplying the extremes by the means,

$$5 \times X = 25 \times 16$$

$$X = \frac{25 \times 16}{5} = \$80$$

Percentage

By definition, percentage means the rate per one hundred, or the proportion in one hundred parts. Therefore 1/100 of a number is called 1 per cent, 2/100, 2 per cent, etc. The symbol % is read as per cent; thus 1%, 2%, etc. Carefully note the following explanation with respect to the symbol %. The notation 5% means 5/100, which, when reduced to a decimal (as is necessary when making a calculation), becomes .05, but .05% has a quite different value; .05% means .05/100, which, when reduced to a decimal, becomes .0005, that is, 5/100 of 1%.

If the decimal has more than two places, the figures that follow the hundredths place signify parts of 1%.

Example—If the list price of shingles is $16 per 1000, what is the net cost for 1000 shingles with a 5% discount for cash?

Reduce % rate to a decimal.

$$5\% = 5/100 = .05$$

Multiply decimal by list price.

$$16 \times .05 = .80$$

Subtract product obtained from list price.

$$\$16 - .80 = \$15.20$$

Powers of Numbers (Involution)

The word "involution" means the multiplication of a quantity by itself any number of times, and a "power" is the product arising from this multiplication. Involution, then, is the process of raising a number to a given power. The "square" of a number is its second power; the "cube," its third power, etc. Thus:

$$\text{square of } 2 = 2 \times 2 = 4$$

$$\text{cube of } 2 = 2 \times 2 \times 2 = 8$$

The power to which a number is raised is indicated by a small "superior" figure called an *exponent*. Thus, in Fig. 1, the exponent indicates the number of times the number, or "root," has been multiplied by itself.

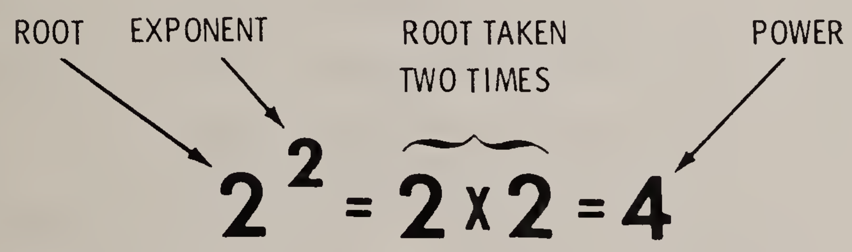


Fig. 1. The "root," "exponent," and "power" of a number.

Roots of Numbers (Evolution)

The word "evolution" means the operation of extracting a root. The root is a factor which is repeated to produce a power. Thus, in the equation $2 \times 2 \times 2 = 8$, 2 is the root from which the power 8 is produced. This number is indicated by the symbol $\sqrt{}$ called the radical sign, which, when placed over a number, means that the root of that number is to be extracted. Thus:

$\sqrt{4}$ *means that the square root of 4 is to be extracted*

The *index* of the root is a small figure which is placed over the radical sign that denotes what root is to be taken. Thus, $\sqrt[3]{9}$ indicates the cube root of 9; $\sqrt[4]{16}$ indicates the extraction of the fourth root of 16. When there is no index given, the radical sign alone always means the *square root* is to be extracted from the number under the radical sign.

Sometimes the number under the radical sign is to be raised to a power before extracting the root, as:

$$\sqrt[3]{4^3} = \sqrt[3]{4 \times 4 \times 4} = \sqrt[3]{64}$$

Example—Extract the square root of 186,624.

$$\begin{array}{rl}
 & \sqrt{18'66'24)}\ 432 \\
 & 16 \\
83 & \sqrt{266} \\
 & 249 \\
862 & \sqrt{\ 1724} \\
 & \underline{1724}
\end{array}$$

From the decimal point, count off the given number into periods of two places each. Begin with the last period counted off (18). The largest square that can be divided into 18 is 4; put this down in the quotient, and put the square (16) under the 18. Write down the remainder (2), and bring down the next period (66). Multiply 4 (in the quotient) by 2 for the first number of the next divisor; 8 goes into 26 three times. Place 3 after 4 in the quotient and also after 8 in the divisor. Multiply the 83 by 3, placing the product 249 under 266, and subtract, obtaining the remainder 17. Bring down the last period (24), and proceed as before, obtaining 432 as the square root of 186,624.

Extracting the cube root of a number is a more complicated though similar process, as indicated by the following procedure:

1. Separate the number into groups of three figures each, beginning at the decimal point.
2. Find the greatest cube that can be divided into the left-hand group, and write its root for the first figure of the required root.

3. Cube this root, subtract the result from the left-hand group, and annex the next group to the remainder for a dividend.
4. For a partial divisor, take three times the square of the root already found, considered as hundreds, and divide the dividend by it. The quotient (or the quotient diminished) will be (or be close to) the second figure of the root.
5. To this partial divisor, add three times the product of the first figure of the root, considered as tens, by the second figure, and to this add the square of the second figure. This sum will be the complete divisor.
6. Multiply the complete divisor by the second figure of the root, subtract the product from the dividend, and annex the next group to the remainder for a new dividend.
7. Proceed in this manner until all the groups have been annexed. The result will be the cube root required, as shown in the following example.

Example—Extract the cube root of the number 50,653.
The solution:

$$\begin{array}{rl} & \sqrt[3]{50'653.}\quad (\,\underline{37} \\ & 27 \\ 2700 & \overline{23\,653} \\ 630 & \underline{23\,653} \\ \underline{49} & \\ 3379 & \end{array}$$

Therefore, the cube root of 50,653 is 37.

MEASURES

To *measure* is the act or process of determining the extent, quantity, degree, capacity, dimensions, volume, etc., of a substance by comparing them with some fixed standard which is usually fixed by law. A measure may relate to any of these standards. There are many types of measures, and practically all of them are standard, but standards vary in different countries.

The measures which are mentioned in this text are all U. S. standards unless designated otherwise. The study of measurements is sometimes called *mensuration*.

Among the many types of measures are the following:

1. Linear—measures of length.
2. Square—used to measure areas.
3. Cubic—used to measure volume, or volumetric contents.
4. Weight—many systems of weights are standard.
5. Time—almost standardized all over the world.
6. Circular or angular—the same all over the world.

Linear Measure

Long Measure

12 inches	=	1 foot		
3 feet	=	1 yard	=	36 inches
5-1/2 yards	=	1 rod	=	16 1/2 feet
40 rods	=	1 furlong	=	660 feet
8 furlongs	=	1 mile	=	5280 feet
3 miles	=	1 league (land)		

(The furlong is practically never used, except at race tracks and in some athletic events.)

Land Surveyor's Measure

7.92 inches	=	1 link		
100 links	=	1 chain	=	66 feet
10 chains	=	1 furlong	=	660 feet
80 chains	=	1 mile	=	5280 feet

The use of the surveyor's chain, or Gunter's chain, was abandoned in the late 1800's and was superseded by the steel tape which is much more accurate; the chain (meaning 66 feet) is still used by the U. S. General Land Office, however, and the term is found in many old deeds. The standard surveyor's tape is often called, from habit, a chain. It is 100 feet long and is graduated in feet except for the last foot, which is divided into tenths and hundredths of a foot.

Nautical Measure (U. S. Navy)

6 feet = 1 fathom

120 fathoms = 1 cable length

The International Nautical Mile (adopted in 1954) = 6076.1033 feet

3 nautical miles = 1 marine league.

The "knot" is a measure of speed, *not* of length, and is equivalent to 1 nautical mile per hour. A speed of 16 knots is equal to 16 nautical miles per hour.

Square Measure

Square measure is used to measure areas. In most, but not all cases, linear units are used to measure the two dimensions, length and width, and their product is the area in square units. Expressed as an equation,

$$\text{length} \times \text{width} = \text{area}$$

The two dimensions, length and width, must be measured in the same units, but any unit of linear measurement may be used. If inches are multiplied by inches, the result will be in square inches; if feet are multiplied by feet, the result will be in square feet, etc.

For the small areas commonly found in everyday life, such as table tops, shelves, etc., the unit most commonly used is the square inch. Plywood and building boards are commonly sold by the square foot. Carpets and other floor coverings and plastering on walls and ceilings are measured in square yards. The carpenter measures roofing by the "square" of 10 × 10 feet, or 100 square feet. Tracts of land are usually measured in acres or, for large areas, in square miles.

Square Measure

144 square inches = 1 square foot

9 square feet = 1 square yard

30¼ square yards = 1 square rod = 272.25 square feet

160 square rods = 1 acre = 4840 square yards or 43,560 square feet

640 acres = 1 square mile = 3,097,600 square yards

36 square miles = 1 township

Cubic Measure

Cubic measure is used to determine or appraise volumes. Three dimensions are involved—length, width, and height—and their product is volume. Expressed as an equation,

$$\text{length} \times \text{width} \times \text{height} = \text{volume}$$

As with square measure, the usual linear units—inches, feet, and yards—are ordinarily used to measure these three dimensions. Most small measurements of capacity, such as small shipping cases, small cabinets, etc., are measured in cubic inches. The contents of buildings, their "cubage," are ordinarily expressed in cubic feet. Earthwork, either excavated and loose or in place, is expressed in cubic yards.

Cubic Measures of Volume

1728 cubic inches = 1 cubic foot

27 cubic feet = 1 cubic yard

Dry Measure—Quantities of loose, granular materials, such as grains, some fruits, and certain vegetables, are measured in arbitrary units which, in turn, are defined by means of cubic measures of volume, usually in cubic inches. Their magnitude is sometimes, but not always, fixed by law.

Dry Measure (U. S.)

2 pints = 1 quart = 67.2 cubic inches

8 quarts = 1 peck = 537.61 cubic inches

4 pecks = 1 bushel = 2150.42 cubic inches

Dry Measure (British and Canadian)

1 gallon = .5 peck = 277.42 cubic inches

4 pecks = 1 bushel = 2219.23 cubic inches

The British dry quart is apparently not often used; it is equal to 69.35 cubic inches, or 1.032 U. S. dry quarts.

The weight, rather than the volume, of grains is the standard fixed by the U. S. Government:

1 bushel of wheat = 60 pounds
1 bushel of barley = 48 pounds
1 bushel of oats = 32 pounds
1 bushel of rye = 56 pounds
1 bushel of corn (shelled) = 56 pounds

Board or Lumber Measure—Timbers and logs are measured in board or lumber measure. The board foot is 1 foot wide, 1 foot long, and 1 inch thick, thereby containing 144 cubic inches. In the retail market, all lumber which is less than 1 inch thick is considered as 1 inch. At the sawmills, the full sizes govern the thickness of the saw kerfs; usually about ¼ inch is allowed for and accounted as sawing loss. Actual finished (dressed) sizes of common lumber, the dimension and timbers for Southern Yellow Pine are:

The standard dressed thickness of 1″ boards is 25/32 inch.
The standard thickness of 2″ dimension boards is 1-5/8 inches.
The standard dressed widths of lumber 2″ thick and less are 3/8″ scant for widths under 8″ and 1/2″ scant for 8″ widths and wider.
The standard dressed widths and thicknesses for lumber and timbers are 3/8″ scant for faces under 8″ wide and 1/2″ scant for 8″ widths and over.

Liquid Measure—Liquid measure is used to measure various liquids such as oils, liquors, molasses, and water.

Liquid Measure

4 gills = 1 pint = 28.875 cubic inches
2 pints = 1 quart = 57.75 cubic inches
4 quarts = 1 gallon = 231 cubic inches

There is no legal standard barrel in the U. S. By custom, a barrel of water is understood to be 31-1/2 gallons. The British barrel is generally 36 Imperial gallons. Crude oil is often disposed of at the wells in barrels of 50 gallons, which refined oils are marketed in barrels of 48 gallons. Owing to this lack of uniformity, it is safest to specify "barrels of 50 gallons," or something of that nature, to avoid misunderstanding. The barrel is sometimes used as a dry measure unit of varying value. For Portland cement, 4 bags = 1 barrel = 4 cubic feet = 376 pounds.

Measures of Weight

The simplest definition of weight is that it is the force with which a body is attracted toward the earth. It is a quantity of heaviness. There are three systems, or standards, of weights used in the United States. They are:

1. Avoirdupois—used for almost all ordinary purposes.
2. Troy—used in weighing precious metals and jewels.
3. Apothecaries — used by pharmacists when compounding drugs.

Avoirdupois Weights

16 drams = 1 ounce
16 ounces = 1 pound
100 pounds = 1 hundredweight
20 hundredweights = 1 ton

In England, the following weights are in common usage:

14 pounds = 1 stone
112 pounds = 1 hundredweight
20 hundredweight = 1 ton = 2240 pounds

The 2240-pound ton is sometimes used in the U. S. for weighing coal at the mines and at customs houses for evaluating shipments from England.

Troy Weights

3.086 grains = 1 carat

24 grains = 1 pennyweight
20 pennyweights = 1 ounce
12 ounces = 1 pound

Apothecaries Weights

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound

This standard of weights is fast becoming obsolete, although pharmacists must necessarily be familiar with it. Manufacturing pharmacists and chemists are rapidly changing to the metric weights, using the metric *gram* as a basis instead of the apothecaries' scruple; 1 scruple = 1.296 grams.

Time Measure

Time is defined as measurable duration. It is the period during which an action or process continues. The basis, or standard, used in our ordinary determination of time is the *mean solar day,* beginning and ending at mean midnight. The word "mean" as used here simply means average; the direct ray of the sun does not move in an exact and uniform path around the equator.

Time Measure

60 seconds	=	1 minute
60 minutes	=	1 hour
24 hours	=	1 day
7 days	=	1 week
30 days (commonly)	=	1 month
365 days	=	1 year
10 years	=	1 decade
100 years	=	1 century
1000 years	=	1 millennium

The length of an *astronomical* year is 365 days, 5 hours, 48 minutes, and 45.51 seconds, or approximately 365-1/4 days. This makes it necessary to add 1 day every 4 years, thus making the "leap" year 366 days.

Circular Measure

This measure is used in astronomy, land surveying, navigation, and in measuring angles of all kinds. Circles of all sizes are divisible into degrees, minutes, and seconds. Note that a degree is *not* a measurement of length. It is 1/360 of the circumference of a circle with any radius.

Circular Measure

60 seconds = 1 minute
60 minutes = 1 degree
360 degrees = 1 circle

The Metric System

The base, or fundamental, unit in the metric system is the meter. The meter is defined as the distance between two scribed marks on a standard bar made of platinum-iridium which is kept in the vaults of the International Bureau of Weights and Measures, near Paris, France. Of course, many other standard meter bars have been made from the measurement on this bar. It is permissible and official to use this measurement in the U. S., and, in fact, the yard, the basis for the English system of measurement, has been defined as exactly 3600/3937 meter, or 1 meter = 39.37 inches.

The advantage, and immeasurably greater convenience, of the metric system over the English system of units lies in the fact that it is expressed in tenths, thereby readily allowing the use of decimals. However, the American public is accustomed to the English units, and they will probably persist in its use for a long time to come. The metric system, however, is in common use all over the world with the exception of some English-speaking peoples. The meter is used like the yard to measure cloth and short distances.

Units of other denominations are named by prefixing to the word "meter" the Latin numerals for the lower denominations and the Greek numerals for the higher denominations, as shown in the following chart:

Lower denomination		*Higher denomination*	
Deci	= 1/10	Deka	= 10
Centi	= 1/100	Hecto	= 100
Milli	= 1/1000	Kilo	= 1000
Micro	= 1/1,000,000	Myria	= 10,000
		Mega	= 1,000,000

Therefore, 1 decimeter = 1/10 of a meter, 1 millimeter = 1/100 of a meter, 1 kilometer = 1000 meters, etc. From this explanation of the metric prefixes, the linear table which follows can easily be understood.

Metric Table of Linear Measure

Metric Denomination				Meter		U. S. value
		1 millimeter	=	.001	=	.0394 in.
10 millimeters	=	1 centimeter	=	.01	=	.3937 in.
10 centimeters	=	1 decimeter	=	.1	=	3.937 in.
10 decimeters	=	1 meter	=	1.	=	39.3707 in.
					=	3.28 ft.
10 meters	=	1 dekameter	=	10.	=	32.809 ft.
10 dekameters	=	1 hectometer	=	100.	=	328.09 ft.
10 hectometers	=	1 kilometer	=	1000.	=	.62138 mi.
10 kilometers	=	1 myriameter	=	10,000	=	6.2138 mi.

The kilometer is commonly used for measuring long distances. The square meter is the unit which is used for measuring ordinary surfaces, such as flooring, ceilings, etc.

Metric Table of Square Measure

100 sq. millimeters (sq. mm.)	= 1 sq. centimeter	= .155 + sq. in.

100 sq. centimeters (sq. cm.)	= 1 sq. decimeter	= 15.5 + sq. in.
100 sq. decimeters (sq. dm.)	= 1 sq. meter (sq. m.)	= 1.196 + sq. yd.

The acre is the unit of land measure and is defined as a square whose side is 10 meters, equal to a square dekameter, or 119.6 square yards.

Metric Table of Land Measure

1 centiare (ca.)	= (1 sq. meter)	= 1.196 sq. yd.
100 centiares (ca.)	= 1 are	= 119.6 sq. yd.
100 ares (A.)	= 1 hectare	= 2.471 acres
100 hectares (ha.)	= 1 sq. kilometer	= .3861 sq. mi.

The cubic meter is the unit which is used for measuring ordinary solids, such as excavations, embankments, etc.

Metric Table of Cubic Measure

1000 cu. millimeters (cu. mm.)	= 1 cu. centimeter	= .061 + cu. in.
1000 cu. centimeters (cu. cm.)	= 1 cu. decimeter	= 61.026 + cu. in.
1000 cu. decimeters (cu. dm.)	= 1 cu. meter	= 35.316 + cu. ft.

The liter is the unit of capacity, both of liquid and of dry measures, and is equivalent to a vessel whose volume is equal to a cube whose edge is one-tenth of a meter, equal to 1.0567 quarts liquid measure, and. .9081 quart dry measure.

Metric Table of Capacity

10 milliliters (mi.)	= 1 centiliter	= .0338 fluid ounces
10 centiliters (cl.)	= 1 deciliter	= .1025 cubic inches
10 deciliters (dl.)	= 1 liter	= 1.0567 liquid quarts
10 liters (l.)	= 1 dekaliter	= 2.64 gallons
10 dekaliters (dl.)	= 1 hectoliter	= 26.418 gallons
10 hectoliters (hl.)	= 1 kiloliter,	= 264.18 gallons
10 kiloliters (kl.)	= 1 myraliter (ml.)	

1 myrialiter	= 10 cu. meters		
		= 283.72 + bu.	= 2641.7 + gal.
1 kiloliter	= 1 cu. meter		
		= 28.372 + bu.	= 264.17 gal.
1 hectoliter	= 1/10 cu. meter		
		= 2.8372 + bu.	= 26.417 gal.
1 decaliter	= 10 cu. dm.		
		= 9.08 quarts	= 2.6417 gal.
1 liter	= 1 cu. dm.		
		= .908 quart	= 1.0567 qt. liquid
1 deciliter	= 1/10 cu. dm.		
		= 6.1022 cu. in.	= .845 gal.
1 milliliter	= 10 cu. cm.		
		= .6102 cu. in.	= .338 fluid oz.
1 centiliter	= 1 cu. cm.		
		= .061 cu. in.	= .27 fluid dr.

The hectoliter is the unit which is used for measuring liquids, grain, fruit, and roots in large quantities. The gram is the unit of weight equal to the weight of a cube of distilled water, the edge of which is 1/100 of a meter and is equal to 15.432 troy grains.

Metric Table of Weight Measure

10 milligrams (mg.)	= 1 centigram	= .15432 + gr. troy
10 centigrams (cg.)	= 1 decigram	= 1.54324 + gr. troy
10 decigrams (dg.)	= 1 gram	= 15.43248 + gr. troy
10 grams (g.)	= 1 dekagram	= .35273 + oz. avoir.
10 dekagrams (Dg.)	= 1 hectogram	= 3.52739 + oz. avoir.
10 hectograms (hg.)	= 1 kilogram	= 2.20462 + lb. avoir.
10 kilograms (kg.)	= 1 myriagram	= 22.04621 + lb. avoir.
10 myriagrams (Mg.)	= 1 quintal	= 220.46212 + lb. avoir.
10 quintals	= 1 ton	= 2204.62125 + lb. avoir.

GEOMETRY

By definition, geometry is that branch of mathematics that deals with space and figures in space. In other words, it is the science of the mutual relations of points, lines, angles, surfaces, and solids, which are considered as having no properties except those arising from extension and difference of situation.

Lines

There are two kinds of lines—straight and curved. A straight line is the shortest distance between two points. A curved line is one which changes its direction at every point. Two lines are said to be parallel when they have the same direction. A horizontal line is one parallel to the horizon or surface of the earth. A line is perpendicular with another line when they are at right angles to each other. These definitions are illustrated in Fig. 2.

Angles

An angle is the difference in direction between two lines proceeding from the same point (called the vertex). Angles are said to be right (90 degrees) when formed by two perpendicular lines, Fig. 3A, acute (less than 90 degrees), when less than a right angle, Fig. 3B, and obtuse (more than 90 degrees), when greater

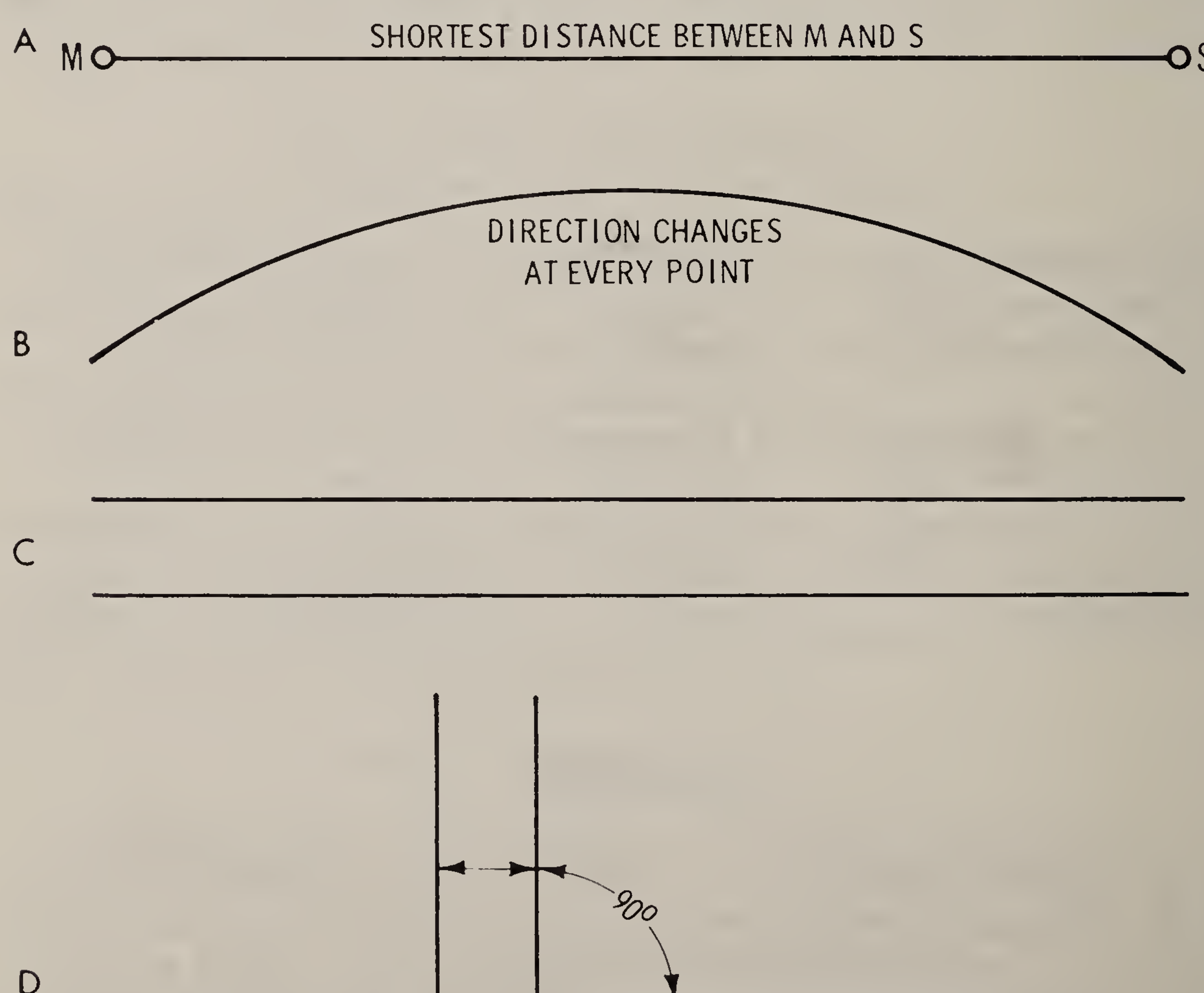


Fig. 2. Various lines; A. Straight; B. Curved; C. Parallel; D. Perpendicular.

than a right angle, Fig. 3C. All angles except right (or 90-degree) angles are called oblique angles.

Angles are usually measured in degrees (circular measure). The *complement* of an angle is the difference between 90 de-

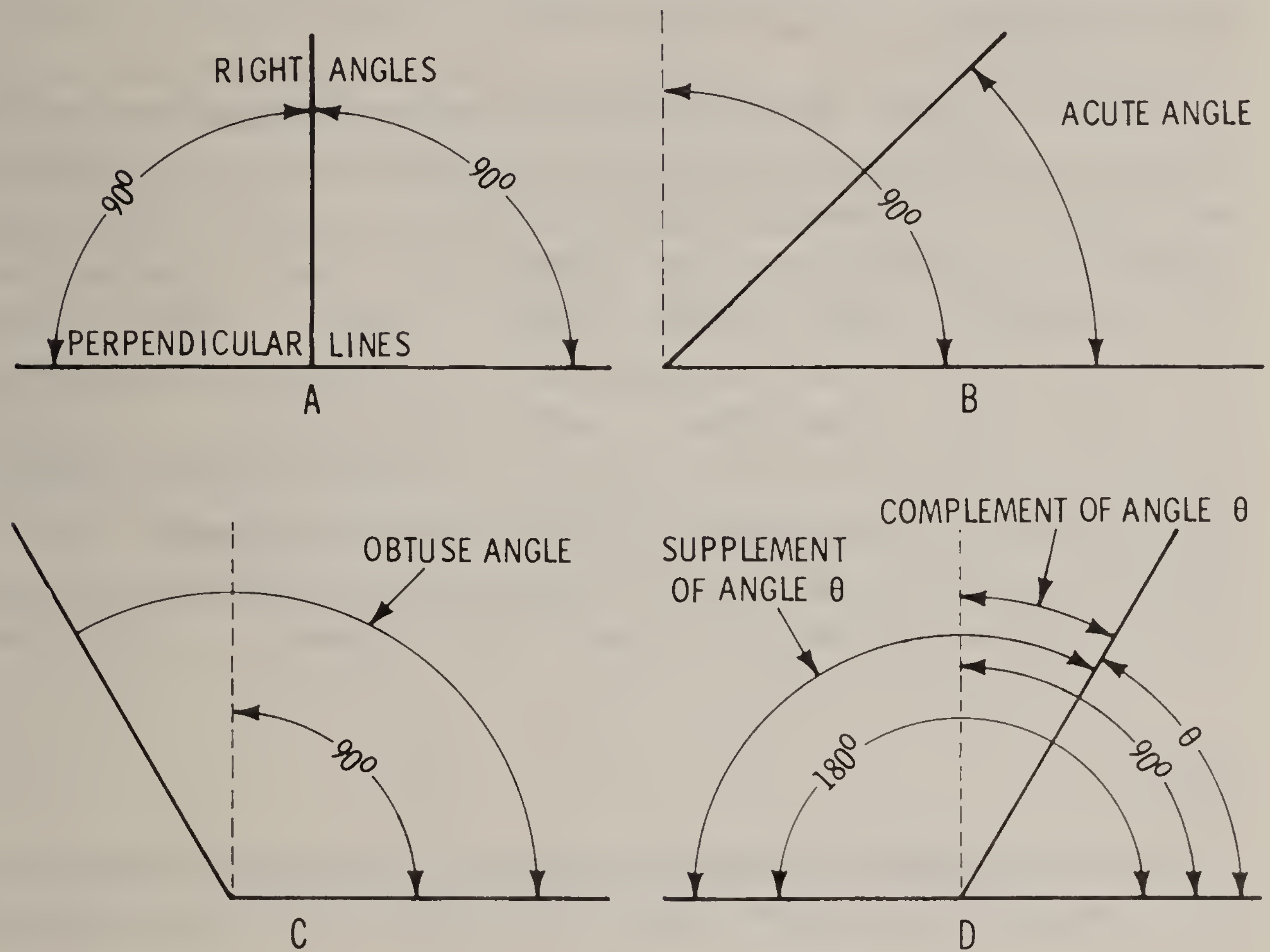


Fig. 3. *Various angles; A. Right; B. Acute; C. Obtuse; D. Compliment and supplement of an angle.*

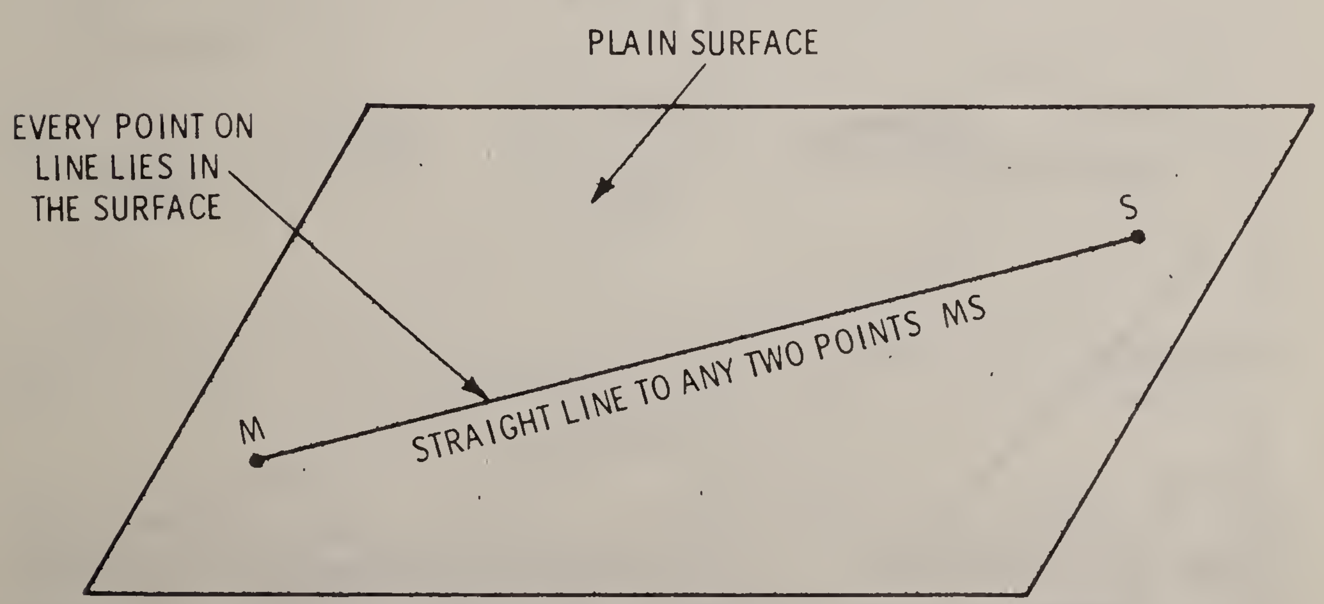


Fig. 4. *The proper conception of a plane surface—every point on a straight line joining any two points in the surface lies in the surface.*

grees and the angle; the *supplement* of the angle is the difference between the angle and 180 degrees. These relations are shown in Fig. 3D.

Plane Figures

The term "plane figures" denotes a plane surface bounded by straight or curved lines. A proper conception of the term "plane" is essential. A plane, or plane surface, is one in which any straight line joining any two points lies wholly in the surface. Fig. 4 defines a plane surface. There is a great variety of plane figures, which are known as polygons when their sides are straight lines. The sum of the sides is called the *perimeter*. A regular polygon has all its sides and angles equal. Plane figures of three sides are known as triangles, Fig. 5, and plane figures of four sides are quadrilaterals, Fig. 6. Various plane figures are formed by curved sides and are known as circles, ellipses, etc., as shown in Fig. 7.

Solids

Solids have three dimensions—length, width, and thickness. The bounding planes are called the *faces*, and the intersections

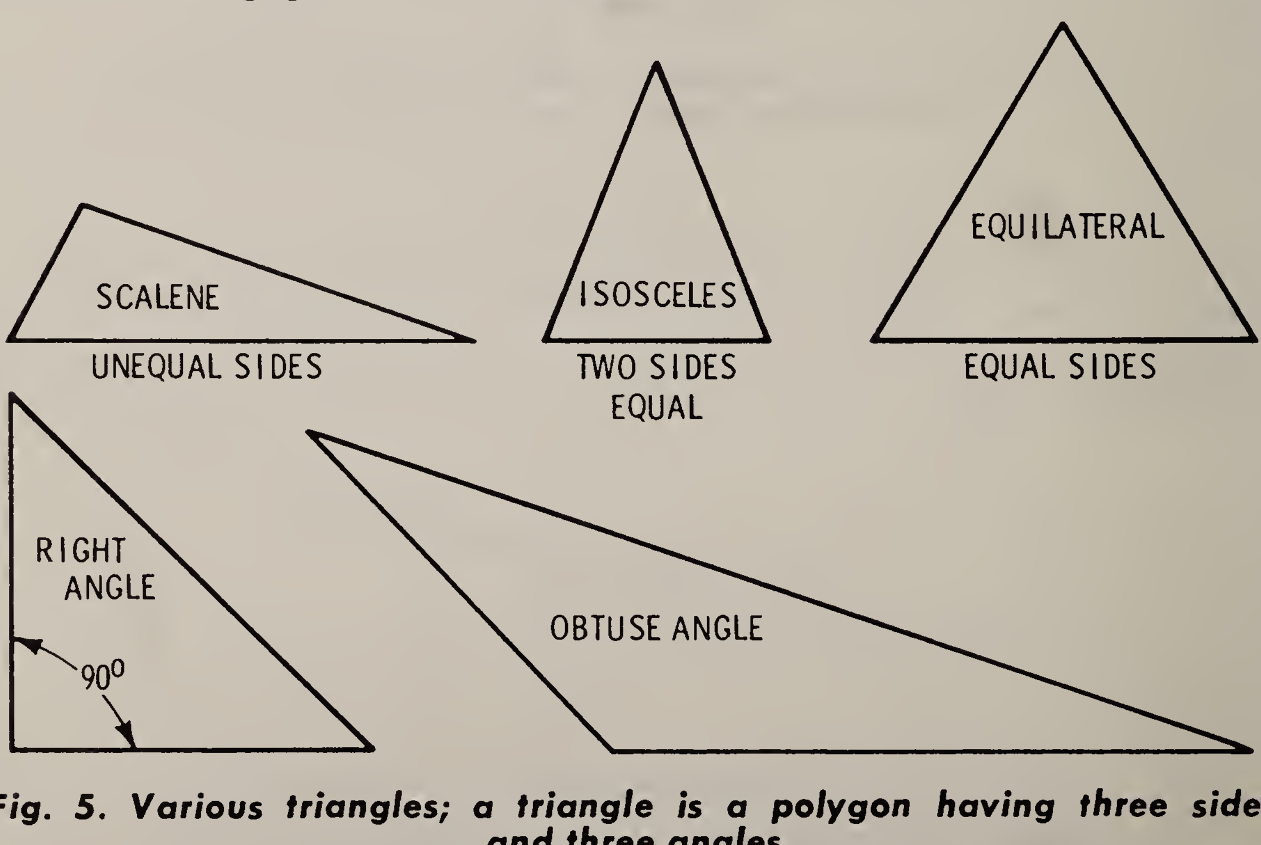


Fig. 5. Various triangles; a triangle is a polygon having three sides and three angles.

are called the *edges.* A prism, as shown in Fig. 9, is a solid whose ends consist of equal and parallel polygons and whose sides are parallelograms. The altitude of a prism is the perpendicular distance of its opposite sides or bases. A parallelopipedon is a prism which is bounded by six parallelograms; the opposite parallelograms are parallel and equal. A cube is a parallelopipedon whose faces are equal. One important solid is the cylinder, which is a body bounded by a uniformly curved surface and having its ends equal and forming parellel circles, as shown in Fig. 10. There are numerous other solids having curved surfaces, such as cones, spheres, etc.

Geometrical Problems

The following problems illustrate the method in which various geometrical figures are constructed, and they are to be solved

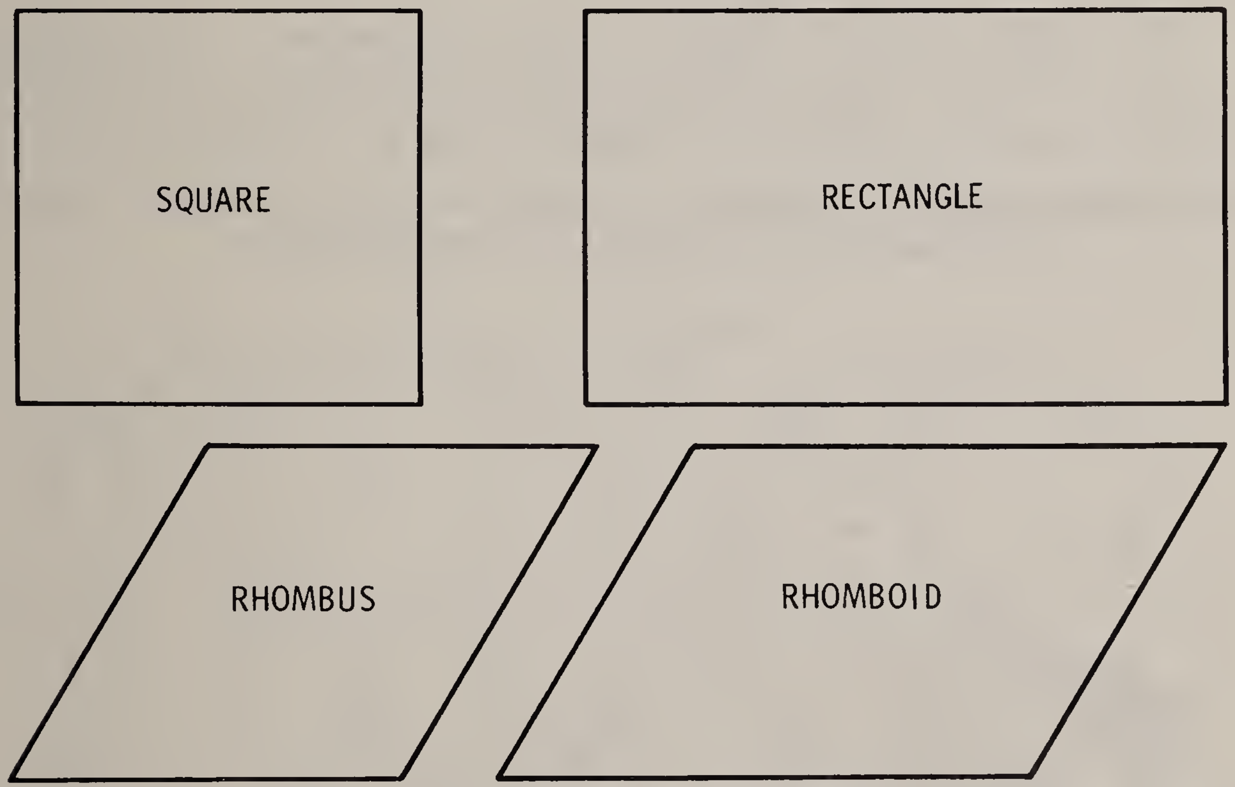


Fig. 6. Various quadralaterals; all opposite sides of a quadralateral are equal.

by the use of pencil, dividers, compass, and scale. Many of these problems are commonly encountered in carpentry with layout work; therefore, proficience in the solution of such problems will be of great value to carpenters or other woodworkers.

Problem 1—To bisect, or divide into two equal parts, a straight line or arc of a circle.

In Fig. 11, from the ends A and B, as centers, describe arcs cutting each other at C and D, and draw line CD, which cuts the line at E, or the arc at F.

Problem 2—To draw a perpendicular to a straight line, or a radial line to an arc.

In Fig. 11, the line CD is perpendicular to AB; also, the line CD is radial to the arc AB.

Problem 3—To erect a perpendicular to a straight line from a given point in that line.

In Fig. 12, with any radius from any given point A, in the line BC describe arcs cutting the line at B and C. Next, with a longer radius describe arcs with B and C as centers, intersecting at D, and draw the perpendicular DA.

Second Method—In Fig. 13, from any point F above BC, describe a circle passing through the given point A and cutting the given line at D; draw DF, and extend it to cut the circle at E; draw the perpendicular AE.

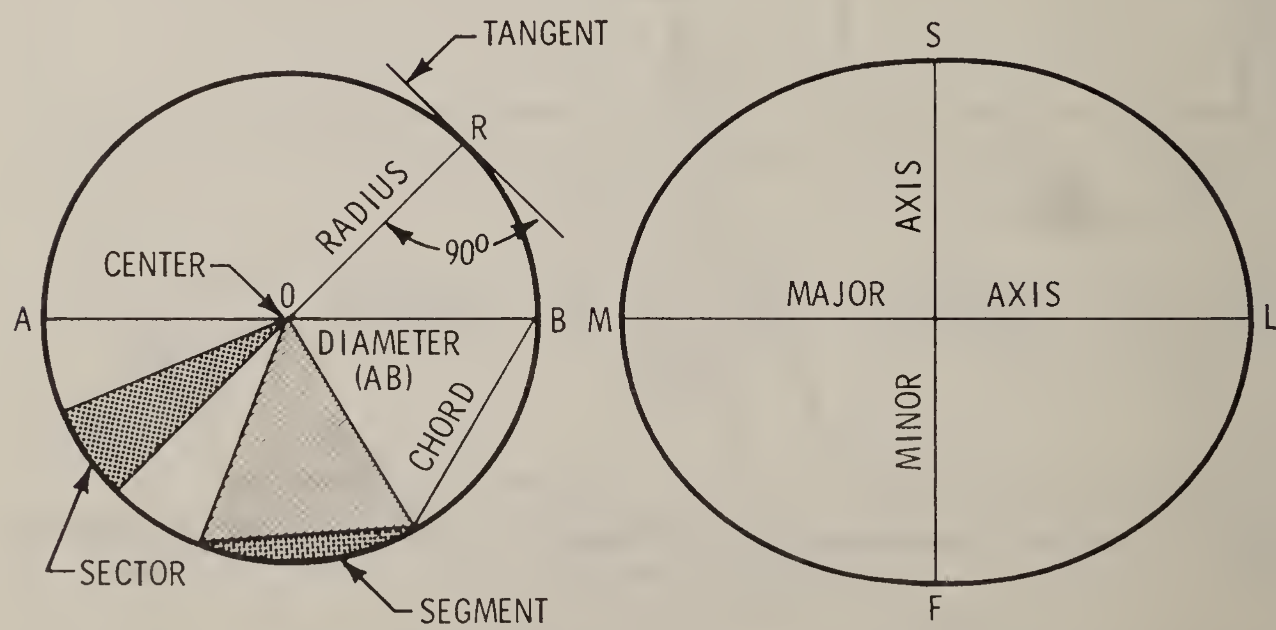


Fig. 7. Curved figures. A circle is a plane figure bounded by a uniformly curved line, every point of which is equidistant from the center point O; OR is a radius, and AB is a diameter. An ellipse is a curved figure enclosed by a curved line which is such that the sum of the distances between any point on the circumference and the two foci is invariable; ML is the major axis, and SF is the minor axis.

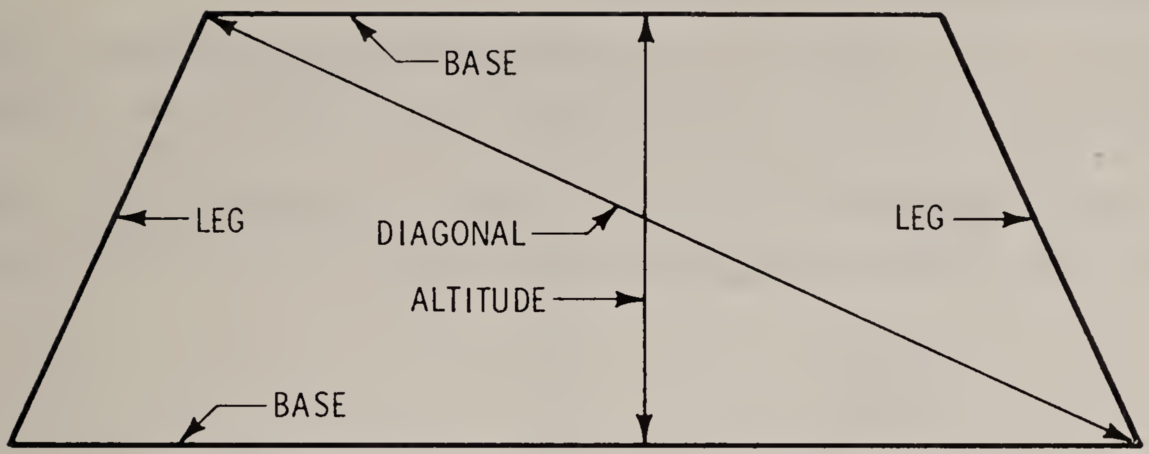


Fig. 8. The parallel sides of a quadralateral (four-sided polygon) are the bases; the distance between the bases is the altitude, and a line joining two opposite vertices is a diagonal.

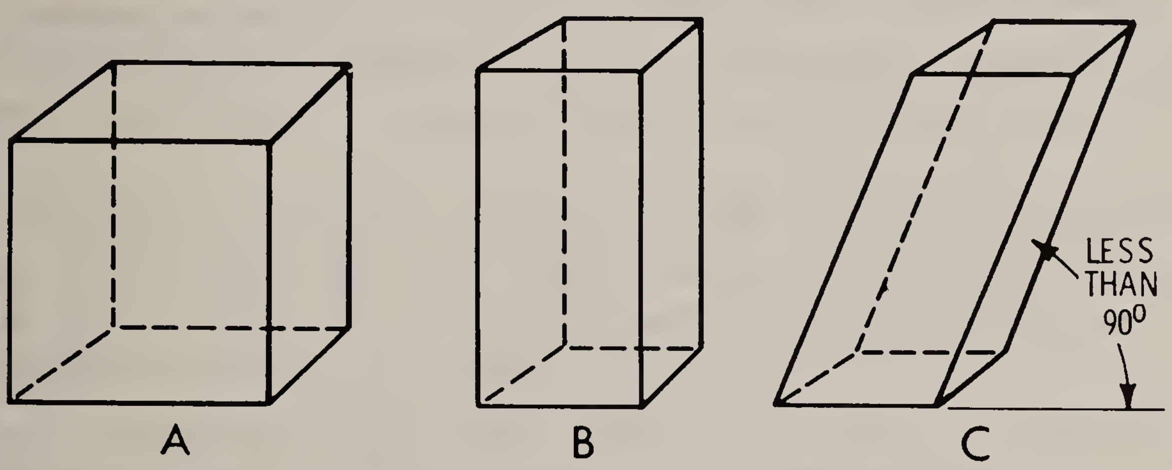


Fig. 9. Various prisms, A. Cube, or equilateral parallelopipedon; B. Parallelopipedon; C. Oblique parallelopipedon.

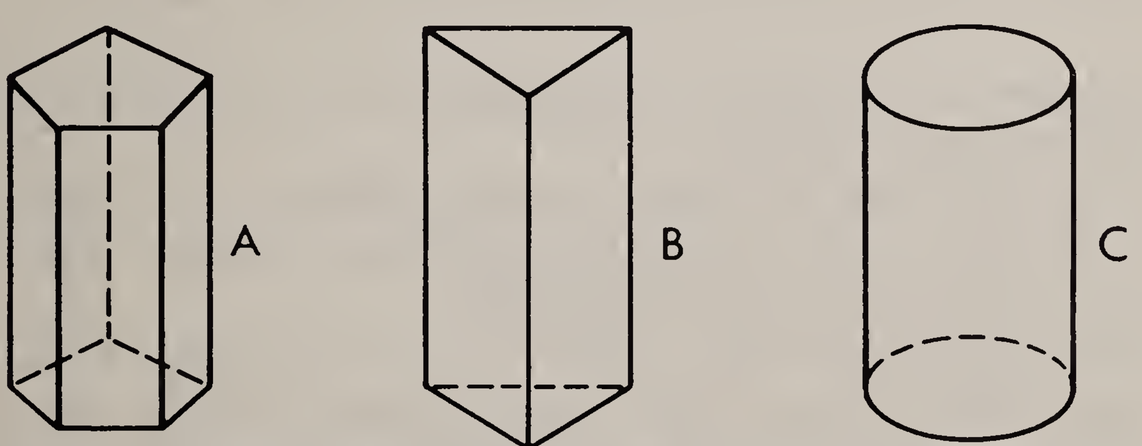


Fig. 10. Various solids; A. Pentagonal prism; B. Triangular prism; C. Cylinder.

Third Method (*boat builders' layout method*)—In Fig. 14, let MS be the given line and A, the given point. From A, measure off a distance AB (4 feet). With centers A and B and radii of 3 and 5 feet, respectively, describe arcs L and F intersecting at C. Draw a line through A and C, which will be the perpendicular

required. This method is used extensively by carpenters when squaring the corners of buildings, but they ordinarily use multiples of 3, 4, and 5, such as 6, 8, and 10, or 12, 16, and 20.

Fourth Method—In Fig. 15, from A, describe an arc EC, and from E with the same radius describe the arc AC, cutting

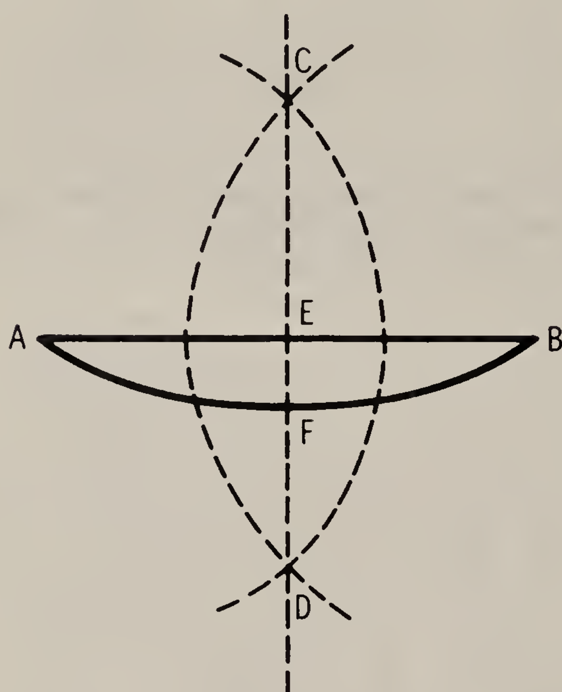


Fig. 11. To bisect a straight line or arc of a circle.

the other at C; through C, draw a line ECD; lay off CD equal to CE, and through D, draw the perpendicular AD. The triangle produced is exactly 60° at E, 30° at D, and 90° at A. The hypotenuse ED is exactly twice the length of the base EA.

Problem 4—To erect a perpendicular to a straight line from any point outside the line.

In Fig. 16, from the point A, with a sufficient radius cut the given line at F and G, and from these points describe acrs cutting at E. Draw the perpendicular AE.

Second Method—In Fig. 17, from any two points B and C at some distance apart in the given line and with the radii BA and CA, respectively, describe arcs cutting at A and D. Draw the perpendicular AD.

Problem 5—To draw a line parallel to a given line through a given point.

In Fig. 18, with C as the center, describe an arc tangent to the given line AB; the radius will then equal the distance from the given point to the given line. Take a point B on the given

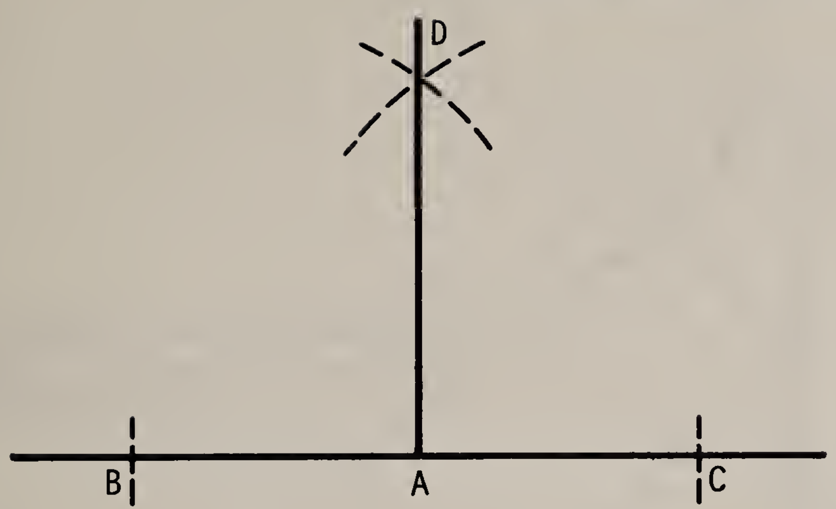


Fig. 12. ***To erect a perpendicular to a straight line from a given point on that line.***

line remote from C, and describe an arc. Draw a line through C, tangent to this arc at D, and it will be parallel to the given line AB.

Second Method—In Fig. 19, from A, the given point, describe the arc FD, cutting the given line at F; from F, with the same radius, describe the arc EA, and lay off FD equal to EA. Draw the parallel line through the points AD.

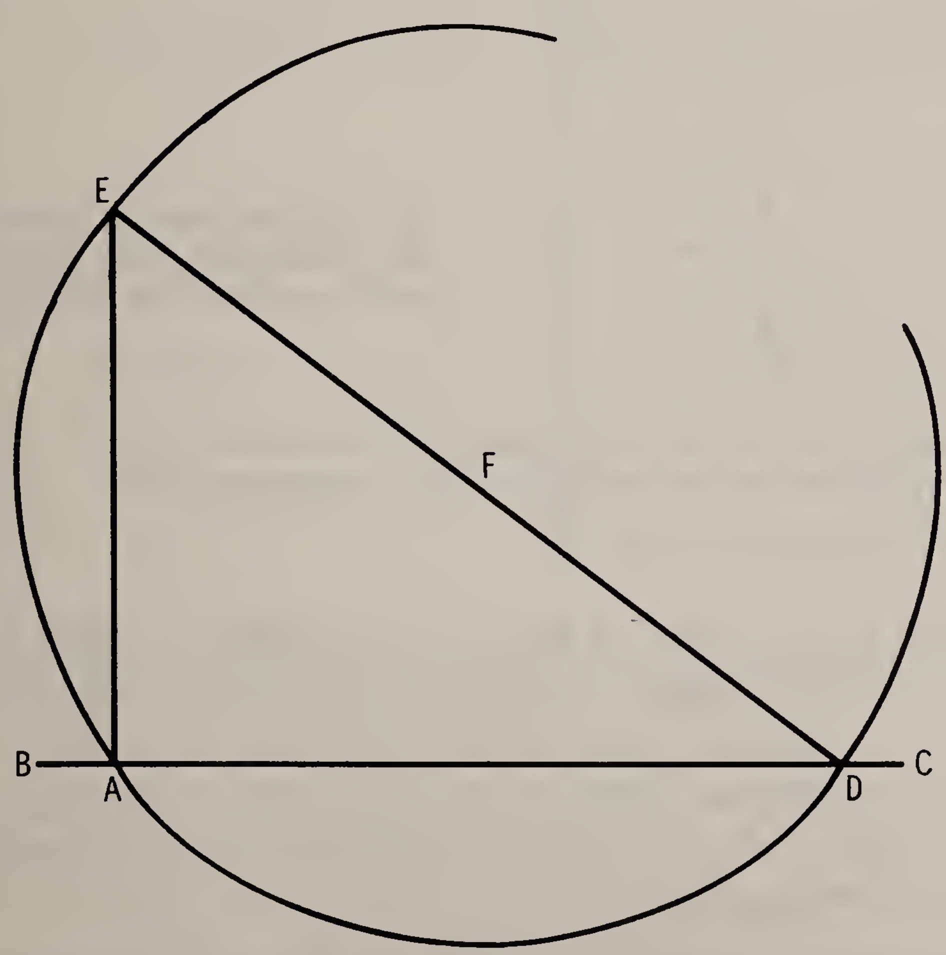


Fig. 13. ***To erect a perpendicular to a straight line from a given point on that line, second method.***

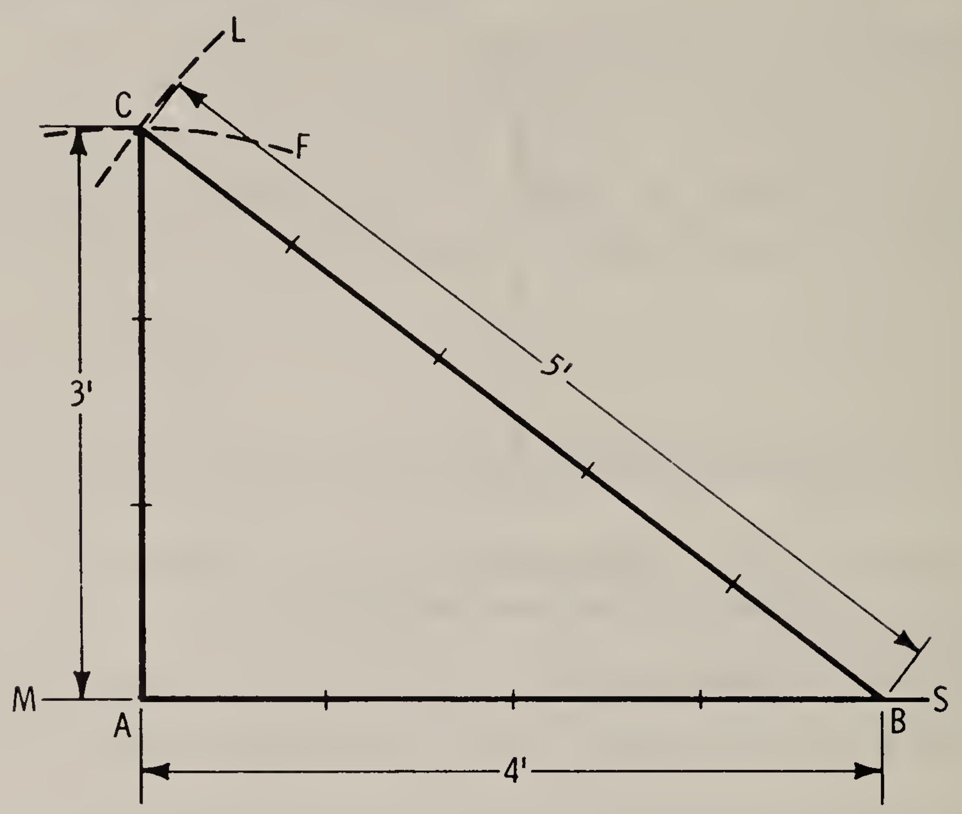


Fig. 14. To erect a perpendicular to a straight line from a given point on that line, third method.

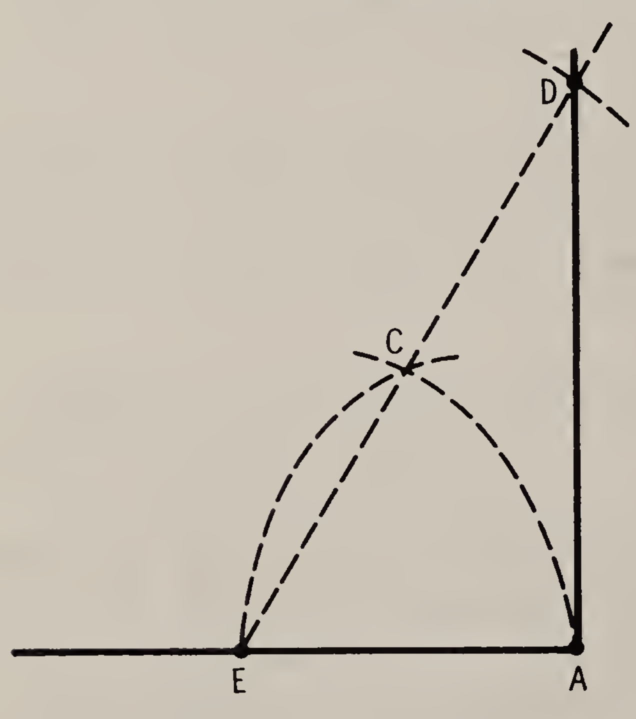


Fig. 15. To erect a perpendicular to a straight line from a given point on that line, fourth method.

Problem 6—To divide a line into a number of equal parts.

In Fig. 20, assuming line AB is to be divided into five equal parts, draw a diagonal line AC of five units in length. Join BC at 5 and through the points 1, 2, 3, 4, draw lines 1L, 2a, etc., parallel to BC. AC will then be divided into five equal parts, AL, La, ar, rf, and fB.

Problem 7—To draw an angle equal to a given angle on a straight line. In Fig. 21, let A be the given angle, and FG the

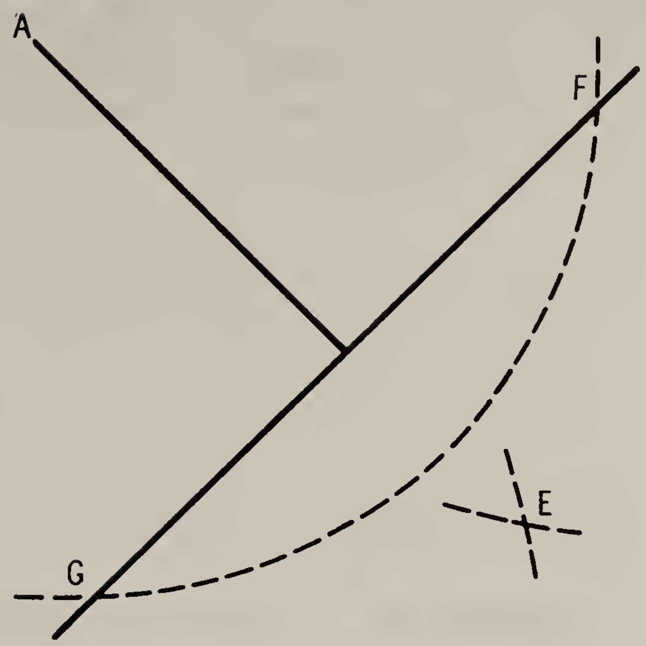


Fig. 16. To erect a perpendicular to a straight line from any point outside the line.

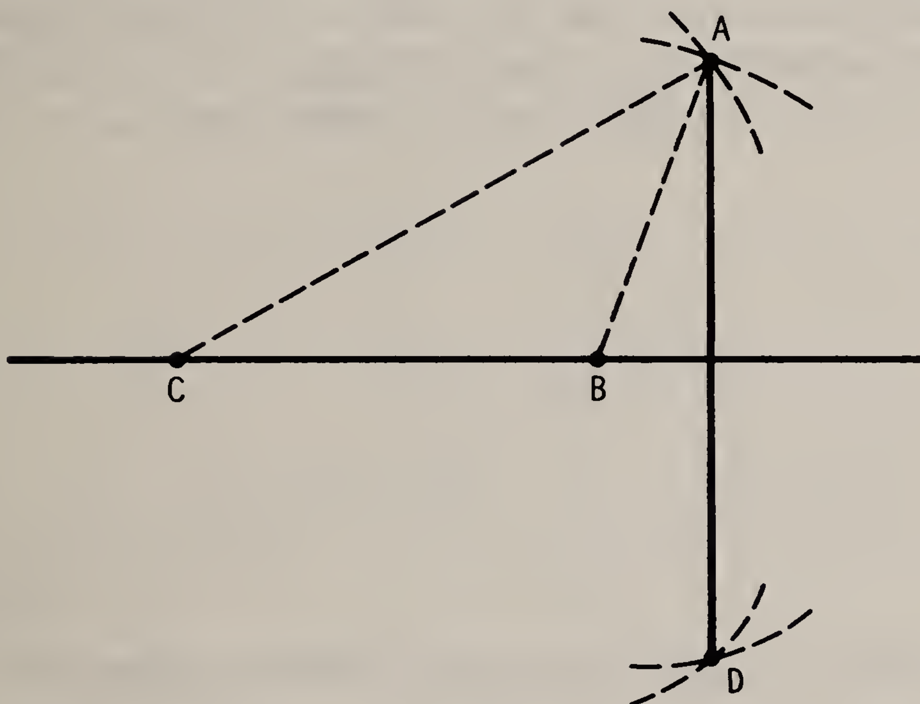


Fig. 17. To erect a perpendicular to a straight line from any point outside the line, second method.

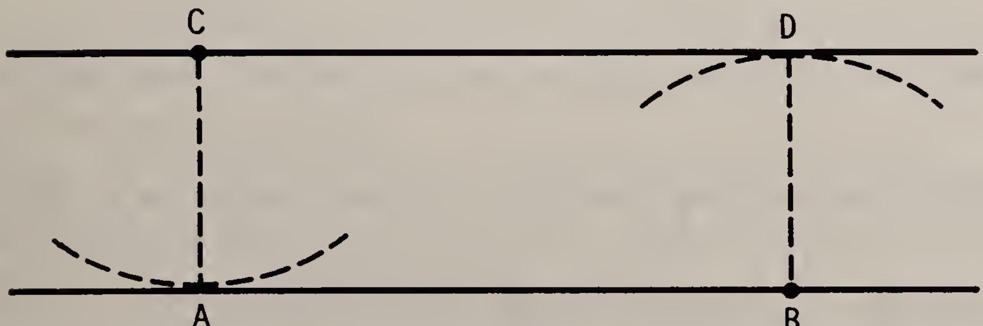


Fig. 18. To draw a line parallel to a given line through a given point.

line. With any radius from the points A and F, describe arcs DE and IH cutting the sides of angle A and line FG. Lay off arc IH equal to arc DE, and draw line FH. Angle F is then equal to A, as required.

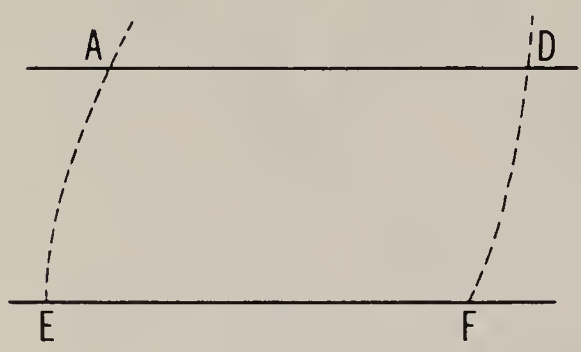


Fig. 19. To draw a line parallel to a given line through a given point, second method.

Problem 8—To bisect an angle.

In Fig. 22, let ACB be the angle; with the center of the angle at C, describe an arc cutting the sides at A and B. Using A and B as centers, describe arcs which intersect at D. A line through C and D will divide the angle into two equal parts.

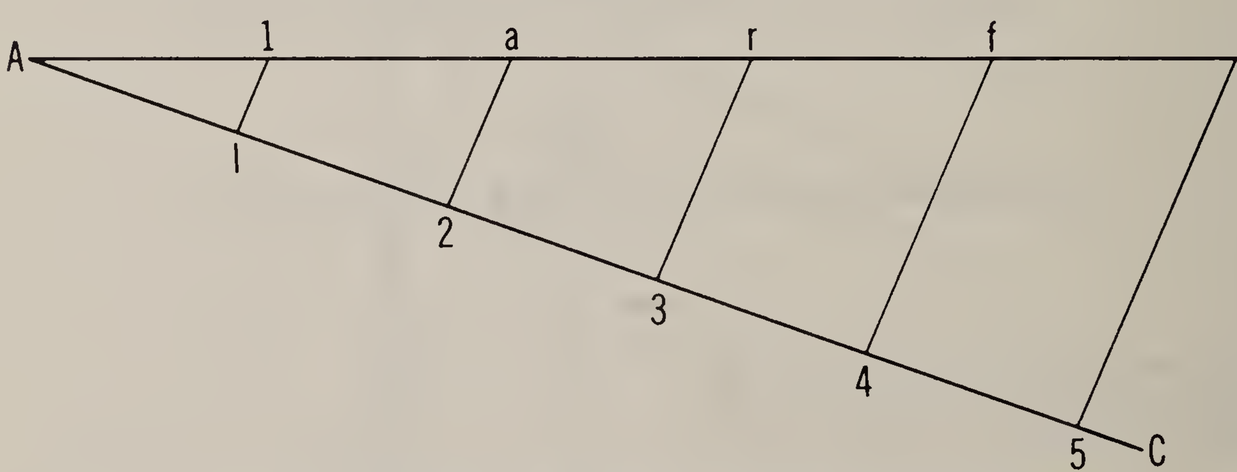


Fig. 20. To divide a line into a number of equal parts.

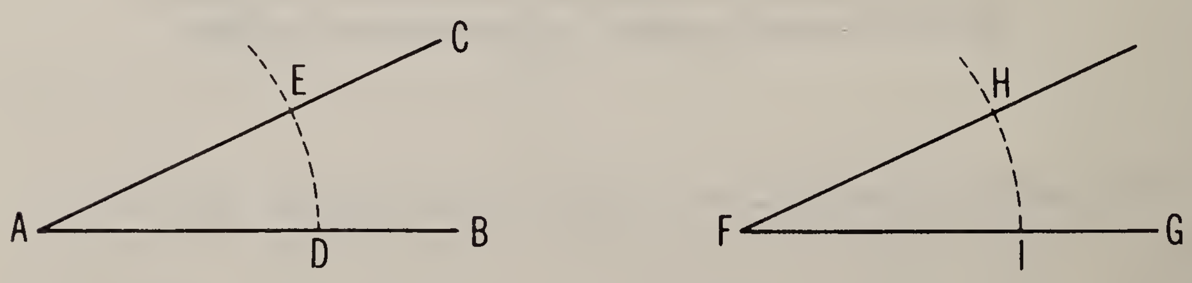
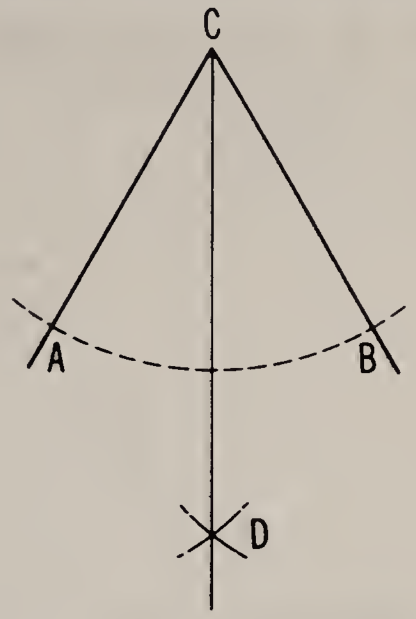


Fig. 21. To draw an angle equal to a given angle on a straight line.

Problem 9—To find the center of a circle.

In Fig. 23, draw any chord MS. With M and S as centers, and with any radius, describe arcs L F and L′ F′, and draw a line

Fig. 22. To bisect an angle.



through their intersection, giving a diameter AB. Applying the same construction with centers A and B, describe arcs ef and e′f′. A line drawn through the intersections of these arcs will cut line AB at O, the center of the circle.

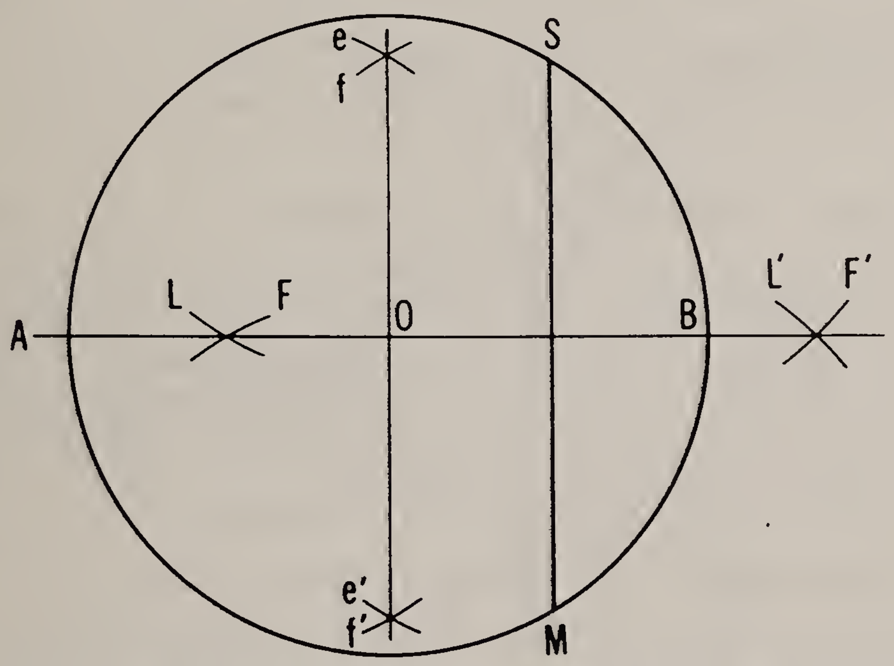


Fig. 23. To find the center of a circle.

Problem 10—To describe an arc of a circle with a given radius through two given points.

In Fig. 24, take the given points A and B as centers, and, with the given radius, describe arcs which intersect at C; from C, with the same radius, describe an arc AB, as required.

Second Method—In Fig. 25, for a circle or an arc, select three points ABC in the circumference which are well apart;

with the same given radius, describe arcs from these three points that intersect each other, and draw two lines, DE and FG, through their intersections. The point where these lines intersect is the center of the circle or arc.

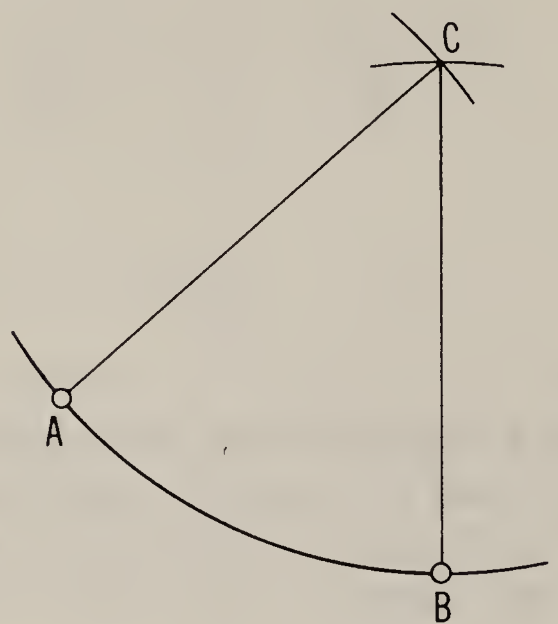


Fig. 24. To describe an arc of a circle with a given radius through two given points.

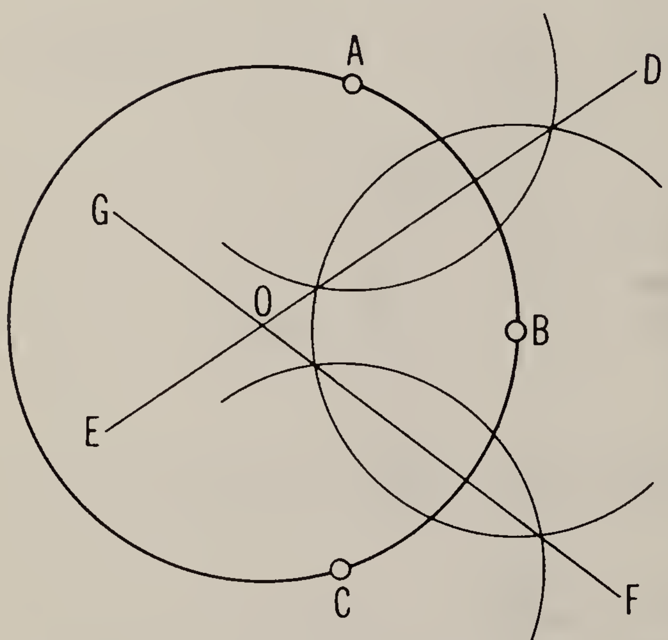


Fig. 25. To describe an arc of a circle with a given radius through two given points, second method.

Problem 11—To describe a circle passing through three given points.

In Fig. 25, let A, B, and C be the given points, and proceed as in the last problem to find the center O from which the circle may be described. This problem is useful in such work as laying out an object of large diameter, such as an arch, when the span and rise are given.

Problem 12—To draw a tangent to a circle from a given point in the circumference.

In Fig. 26, from A, lay off equal segments AB and AD; join line BD, and draw line AE parallel to BD for the tangent.

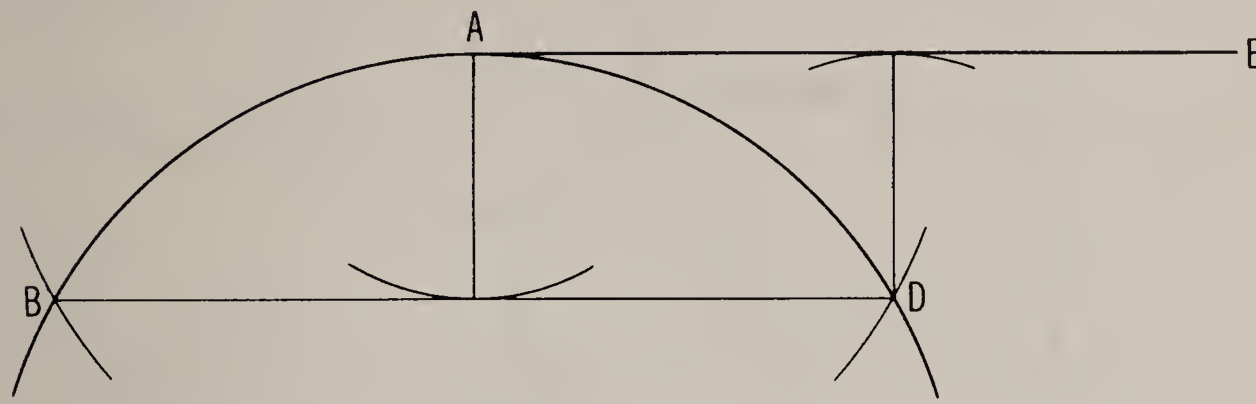


Fig. 26 To draw a tangent to a circle from a given point in the circumference.

Problem 13—To draw tangents to a circle from points outside the circle.

In Fig. 27, from A, and with the radius AC, describe an arc BCD; from C, with a radius equal to the diameter of the circle, intersect the arc at BD; join BC and CD, which intersect the circle at E and F, and draw the tangents AE and AF.

Problem 14—To describe a series of circles tangent to two inclined lines and tangent to each other.

In Fig. 28, bisect the inclination of the given lines AB and CD by the line NO. From a point P in this line, draw the perpendicular PB to the line AB, and on P, describe the circle BD, touching the lines and the center line at E. From E, draw EF perpendicular to the center line intersecting AB at F, and from F, describe an arc EG intersecting AB at G. Draw GH parallel to BP, thus producing H, the center of the next circle, to be described with the radius HE, and so on for the next circle IN.

Problem 15—To construct an equilateral triangle on a given base.

In Fig. 29, with A and B as centers and a radius equal to AB, describe arcs 1 and f. At their intersection C, draw lines CA and CB, which are the sides of the required triangle. If the sides are to be unequal, the process is the same, taking as the radii the lengths of the two sides to be drawn.

Problem 16—To construct a square on a given base.

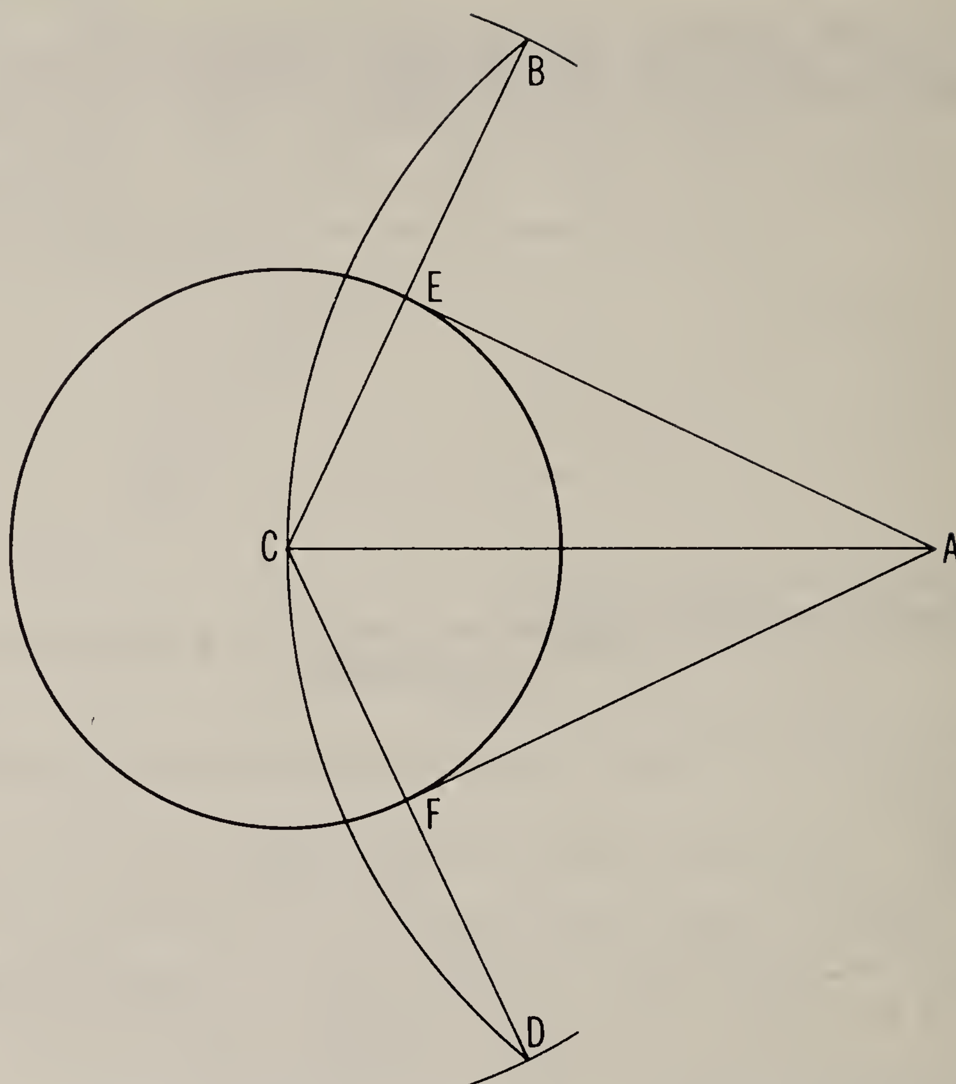


Fig. 27. To draw tangents to a circle from points outside the circle.

In Fig. 30, with end points A and B of the base as centers and a radius equal to AB, describe arcs which intersect at C; on C, describe arcs which intersect the others at D and E, and on D and E, intersect these arcs F and G. Draw AE and BG, and join the intersections HI to form the square AHIB.

Problem 17—To construct a rectangle on a given base.

In Fig. 30, let AB be the given base. Erect a perpendicular at A and at B equal to the altitude of the rectangle, and join their ends F and G by line FG; AFGB is the rectangle required.

Problem 18—To construct a parallelogram given the sides and an angle.

In Fig. 31, draw side DE equal to the given length A, and lay off the other side DF, equal to the other length B, thus forming the given angle C. From E, with DF as the radius, describe an

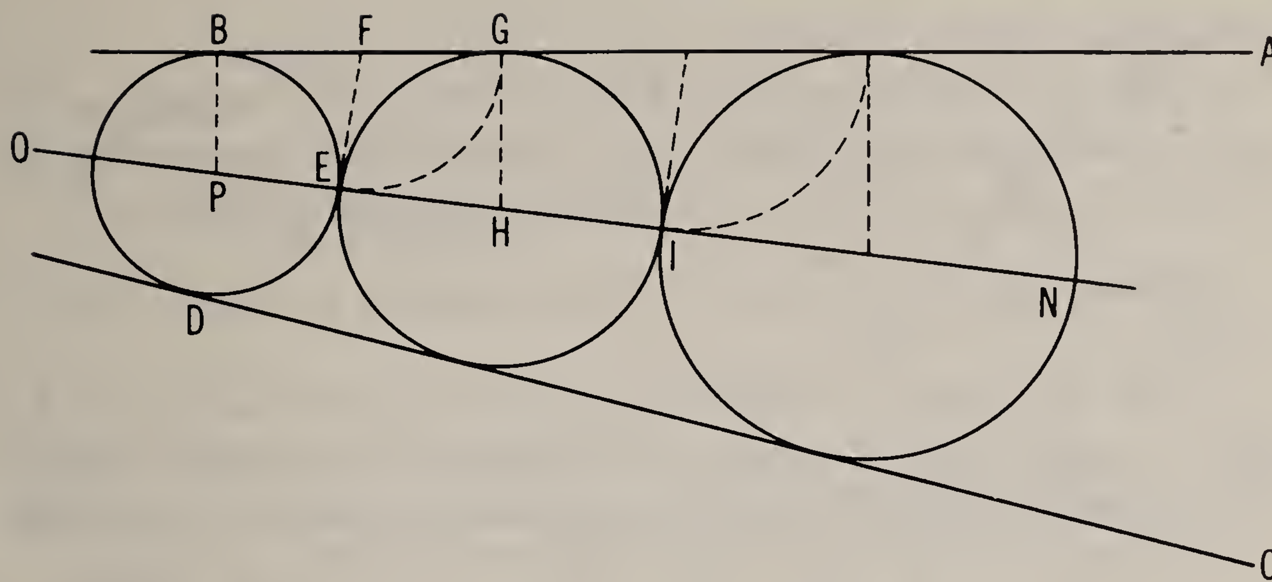


Fig. 28. To describe a series of circles tangent to two inclined lines and tangent to each other.

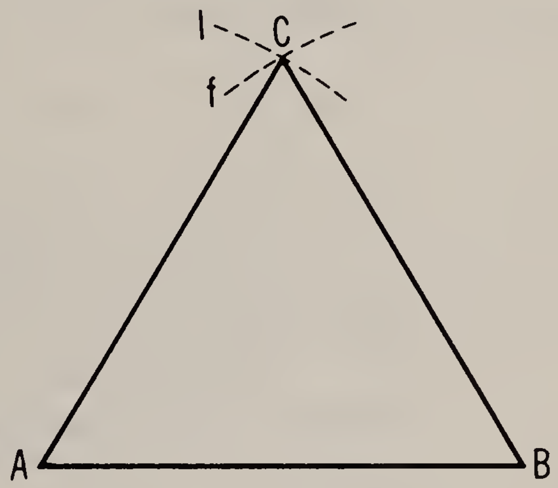


Fig. 29. To construct an equilateral triangle on a given base.

arc, and from F, with the radius DE, intersect the arc at G. Draw FG and EG. The remaining sides may also be drawn as parallels to DE and DF.

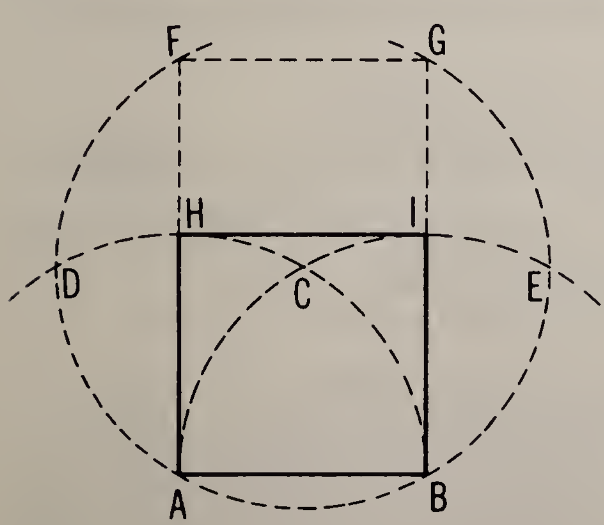


Fig. 30. To construct a square or a rectangle on a given base.

Problem 19—To describe a circle about a triangle.

In Fig. 32, bisect two sides AB and AC of the triangle at E and F, and from these points draw perpendiculars intersecting at K. From K, with radius KA or KC, describe the circle ABC.

Problem 20—To circumscribe and inscribe a circle about a square.

In Fig. 33, draw the diagonals AB and CD intersecting at E. With a radius EA, circumscribe the circle. To inscribe a circle, draw a perpendicular from the center (as just found) to one side of the square, as line OM. With radius OM, inscribe the circle.

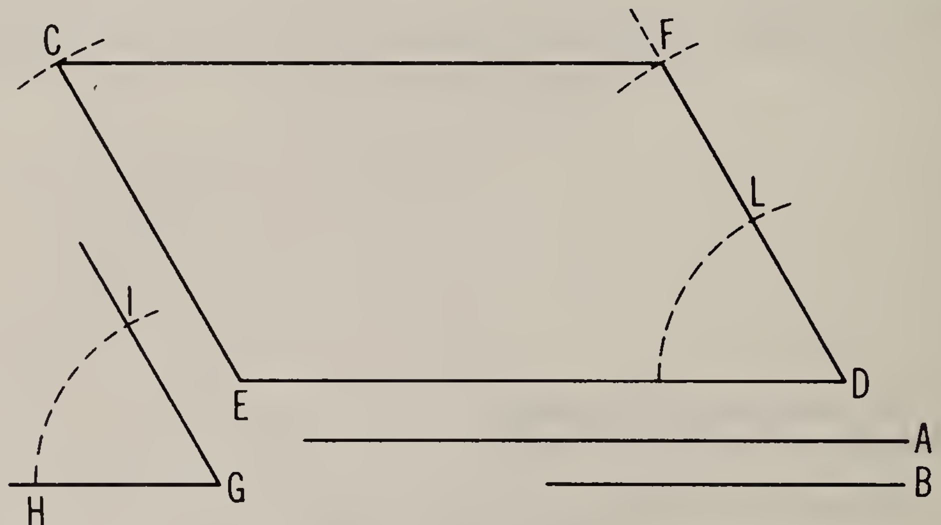


Fig. 31. To construct a parallelogram given the sides and an angle.

Problem 21—To circumscribe a square about a circle.

In Fig. 34, draw diameters MS and LF at right angles to each other. At points M, L, S, and F, where these diameters intersect the circle, draw tangents, that is, lines perpendicular to the diameters, obtaining the sides of the circumscribed square ABCD.

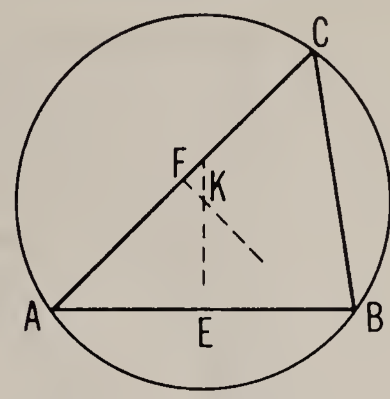
Problem 22—To inscribe a circle in a triangle.

In Fig. 35, bisect two angles A and C of the triangle with lines that intersect at D; from D, draw a perpendicular DE to any side. With DE as the radius, describe a circle.

Problem 23—To inscribe a pentagon in a circle.

In Fig. 36, draw two diameters AC and BD at right angles intersecting at O; bisect AO at E, and from E, with radius EB, AC at F; from B, with radius BF, intersect the circumference at G

Fig. 32. To describe a circle about a triangle.



and H, and with the same radius, step round the circle to I and K; join the points thus found to form the pentagon BGIKH.

Problem 23A—To inscribe a five-pointed star in a circle.

In Fig. 37, proceed as explained for the inscribed pentagon in Problem 23. Then, connect point B with points K and I, point H with points G and I, etc. The star is mathematically correct.

Problem 24—To construct a hexagon from a given straight line.

In Fig. 38, from A and B. the ends of the given line, describe arcs intersecting at g; from g, with the radius gA, describe a circle. With the same radius, lay off arcs AG, GF, BD, and DE. Join the points thus found to form the hexagon.

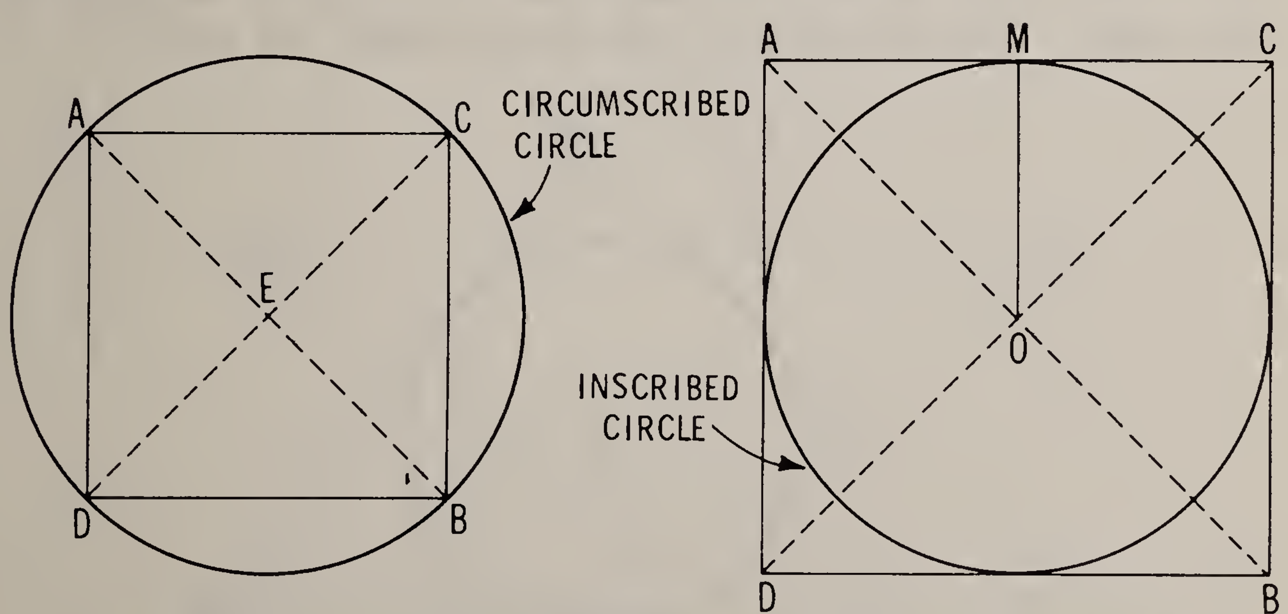


Fig. 33. To circumscribe and inscribe a circle about a square.

Problem 25—To inscribe a hexagon in a circle.

In Fig. 39, draw a diameter ACB; from A and B, as centers with the radius of the circle AC, intersect the circumference at

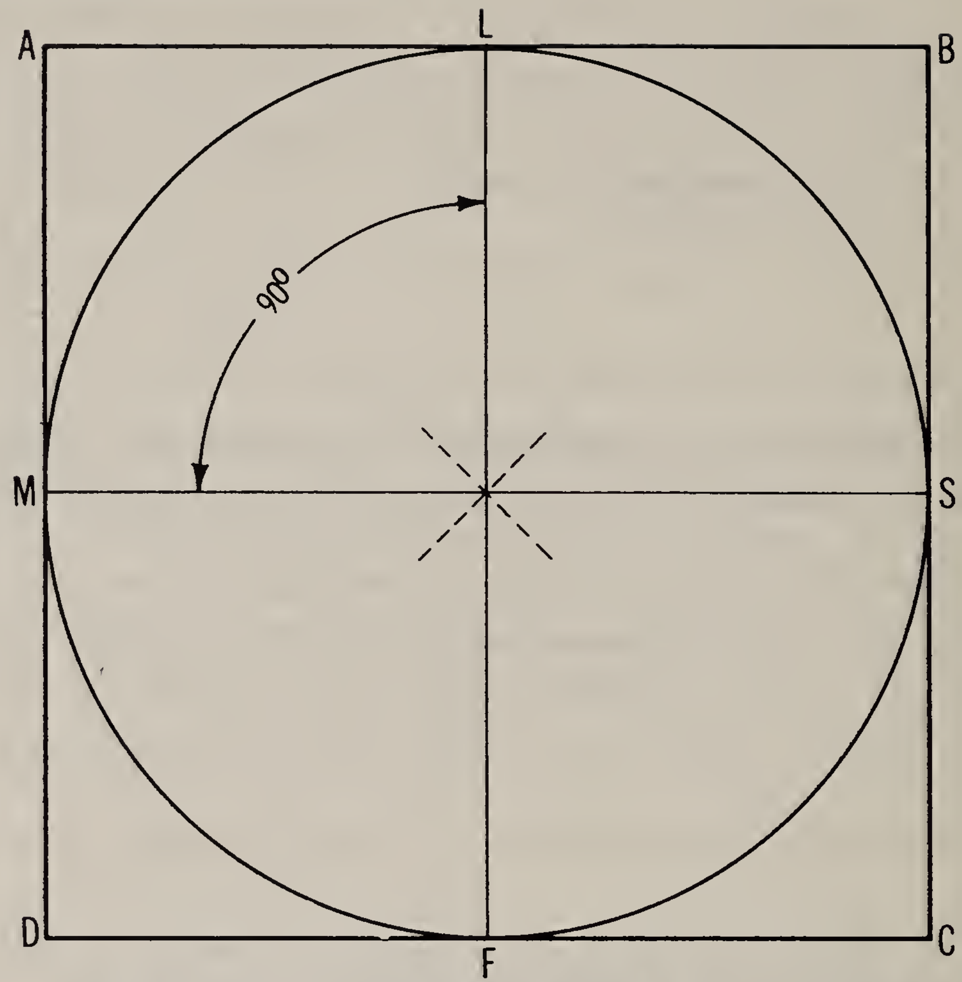


Fig. 34. To circumscribe a square about a circle.

D, E, F, and G, and draw lines AD, DE, etc., to form the hexagon. The points D, E, etc., may also be found by stepping off the radius (with the dividers) six times around the circle.

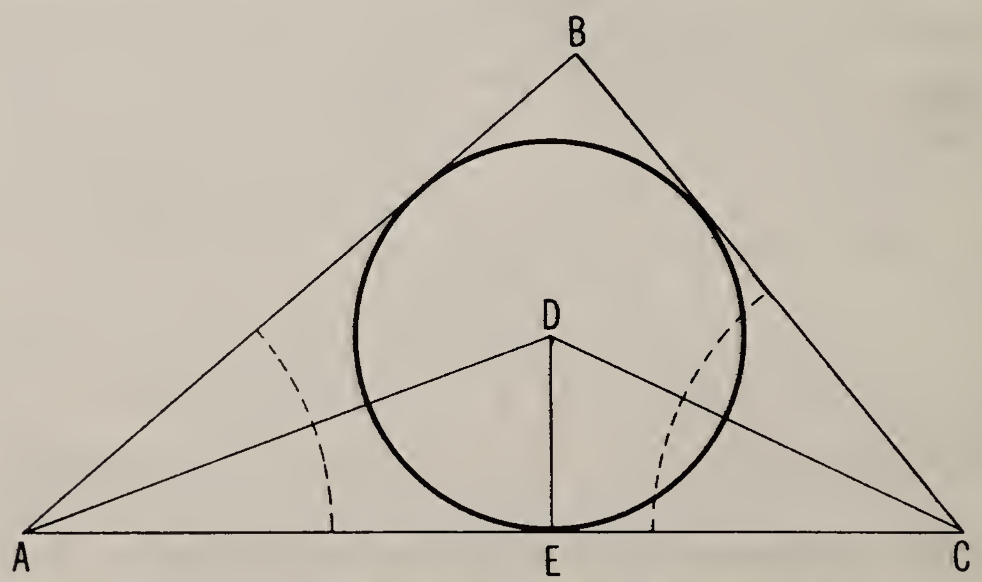


Fig. 35. To inscribe a circle in a triangle.

Problem 26—To describe an octagon on a given straight line.
In Fig. 40, extend the given line AB both ways, and draw perpendiculars AE and BF; bisect the external angles A and B by

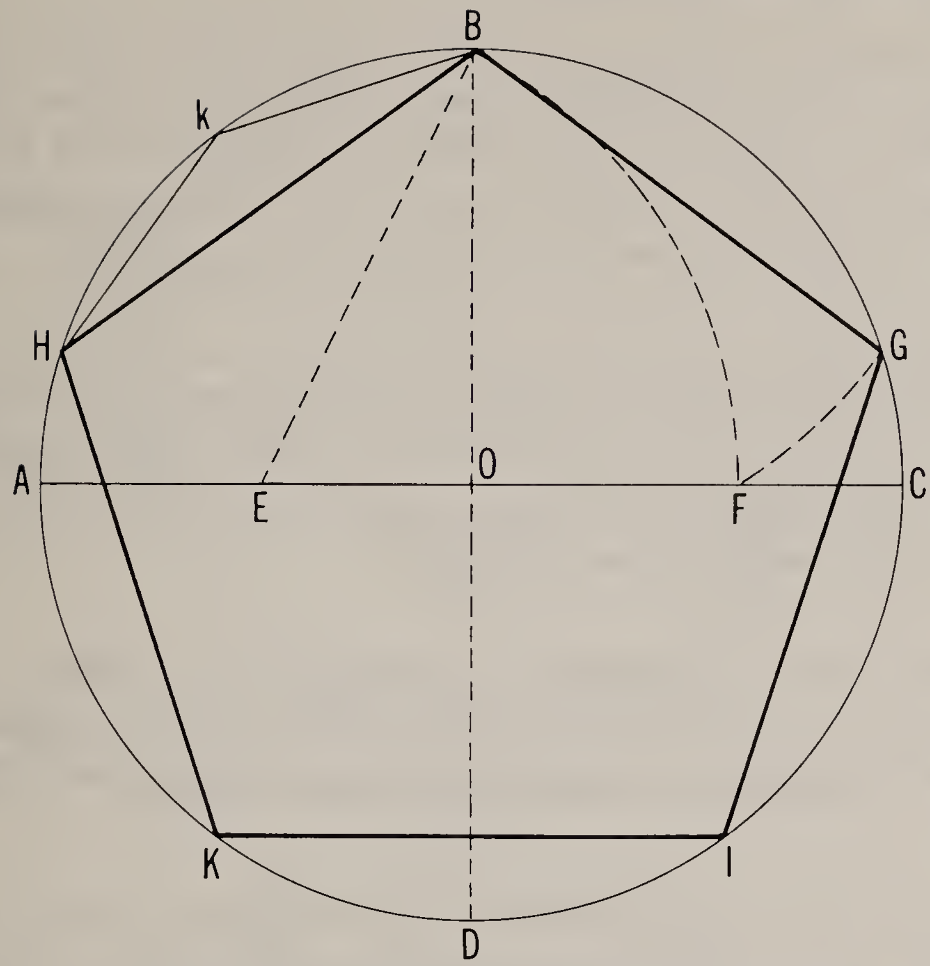


Fig. 36. To inscribe a pentagon in a circle.

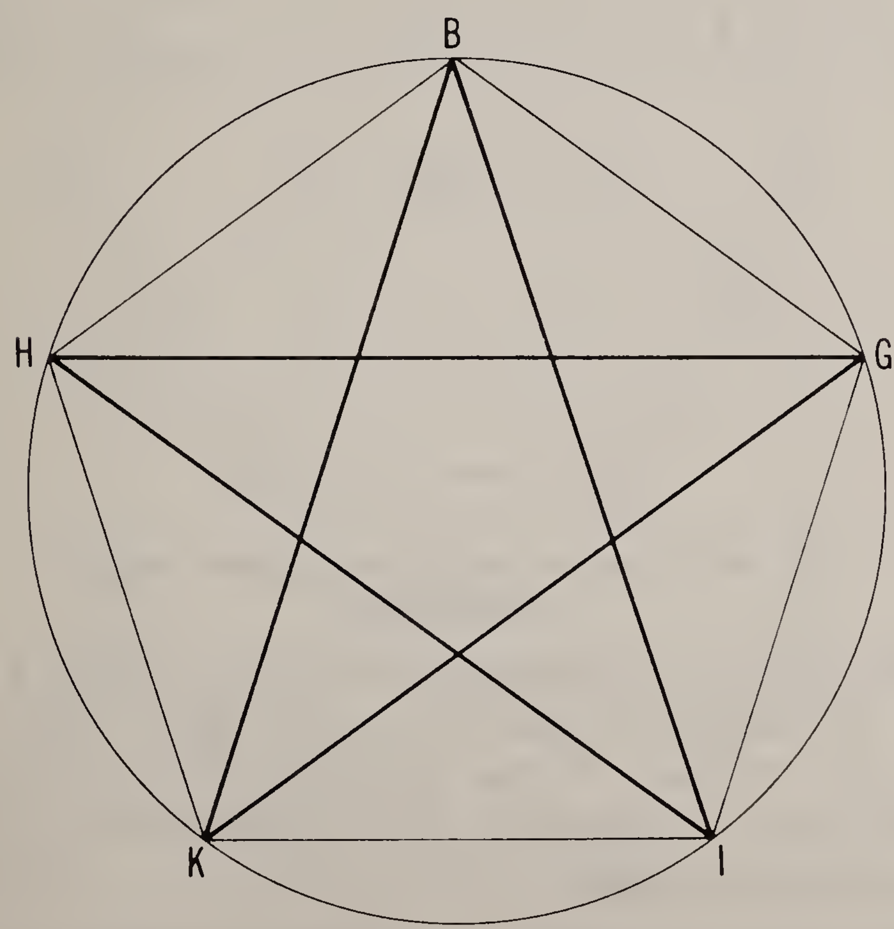


Fig. 37. To inscribe a five-pointed star in a circle.

lines AH and BC, which are made equal to line AB. Draw CD and HG parallel to AE and equal to line AB. Draw CD and HG parallel to AE and equal to line AB; with G and D as centers, and with the radius equal to AB; intersect the perpendiculars at E and F, and draw line EF to complete the hexagon.

Problem 27—To inscribe an octagon in a square.

In Fig. 41, draw the diagonals of the square intersecting at e; from the corners A, B, C, D, with Ae as the radius, describe arcs intersecting the sides of the square at g, h, etc., and join the points thus found to complete the octagon.

Problem 28—To inscribe an octagon in a circle.

In Fig. 42, draw two diameters AC and BD at right angles; bisect the arcs AB, BC, etc., at e, f, etc., to form the octagon.

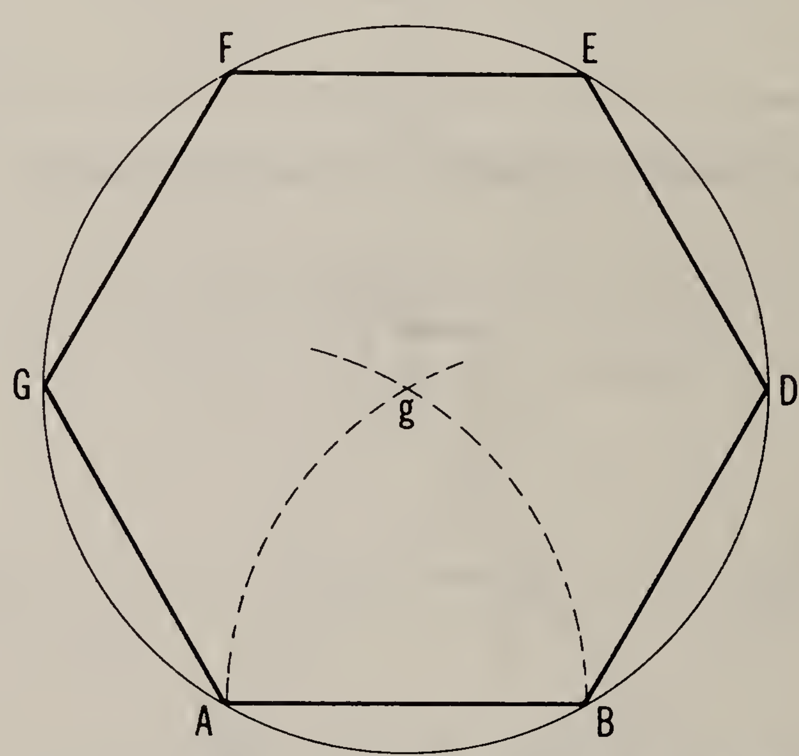


Fig. 38. To construct a hexagon from a given straight line.

Problem 29—To circumscribe an octagon about a circle.

In Fig. 43, describe a square about the given circle AB; draw perpendiculars hk, etc., to the diagonals, touching the circle, to form the octagon. The points h, k, etc., may be found by cutting the sides from the corners.

Problem 30—To describe an ellipse when the two axes are given.

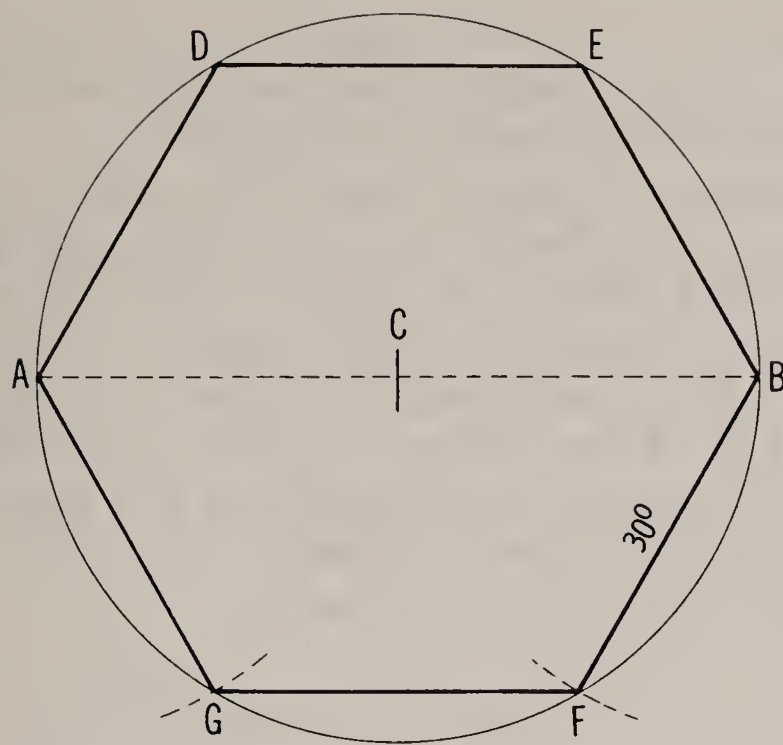


Fig. 39. To inscribe a hexagon in a circle.

In Fig. 44, draw the major and minor axes AB and CD, respectively, at right angles intersecting at E. On C, with AE as the radius, intersect the axis AB at F and G, the *foci;* insert pins through the axis at F and G, and loop a thread or cord on them equal in length to the axis AB, so that when stretched, it

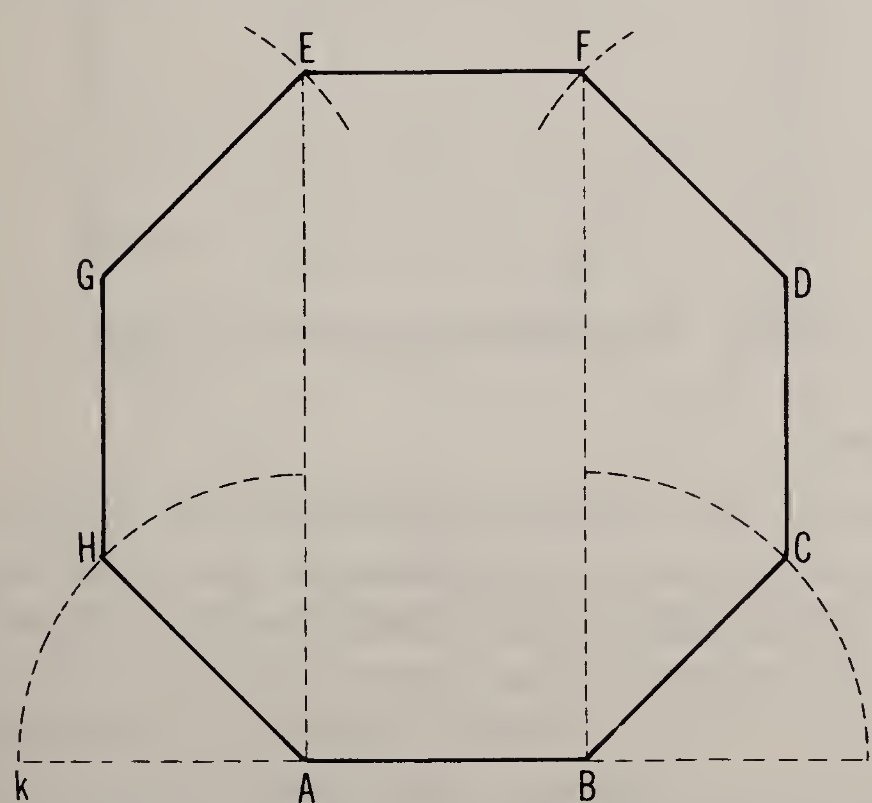


Fig. 40. To describe an octagon on a given straight line.

reaches extremity C of the *conjugate axis,* as shown in dotted lines. Place a pencil inside the cord, as at H, and, by guiding the pencil in this manner, describe the ellipse.

Second Method—Along the edge of a piece of paper, mark off a distance ac equal to AC, one-half the major axis, and from the same point a distance ab equal to CD, one-half the minor axis, as shown in Fig. 45. Place the paper so as to bring point b on the line AB, or major axis, and point c on the line DE, or minor axis. Lay off the position of point a. By shifting the paper so that point b travels on the major axis and point c travels on the minor axis, any number of points in the curve may be found through which the curve may be traced.

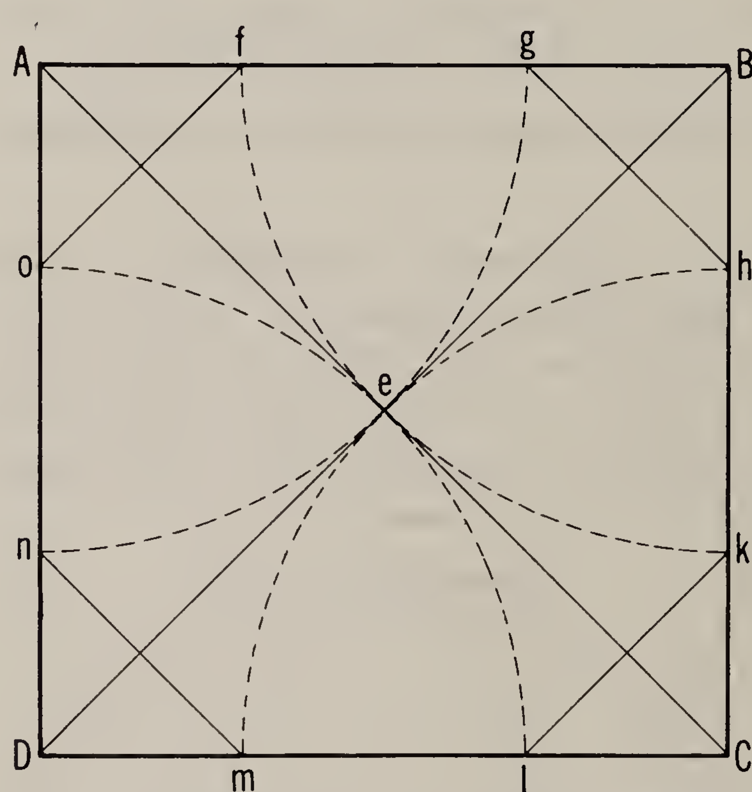


Fig. 41. To inscribe an octagon in a square.

Mensuration

By definition, mensuration is the act, art, or process of measuring. It is that branch of mathematics that deals with finding the length of lines, the area of surfaces, and the volume of solids. Therefore, the problems which follow will be divided into three groups, as:

1. Measurement of lines.
    a. One dimension—length.

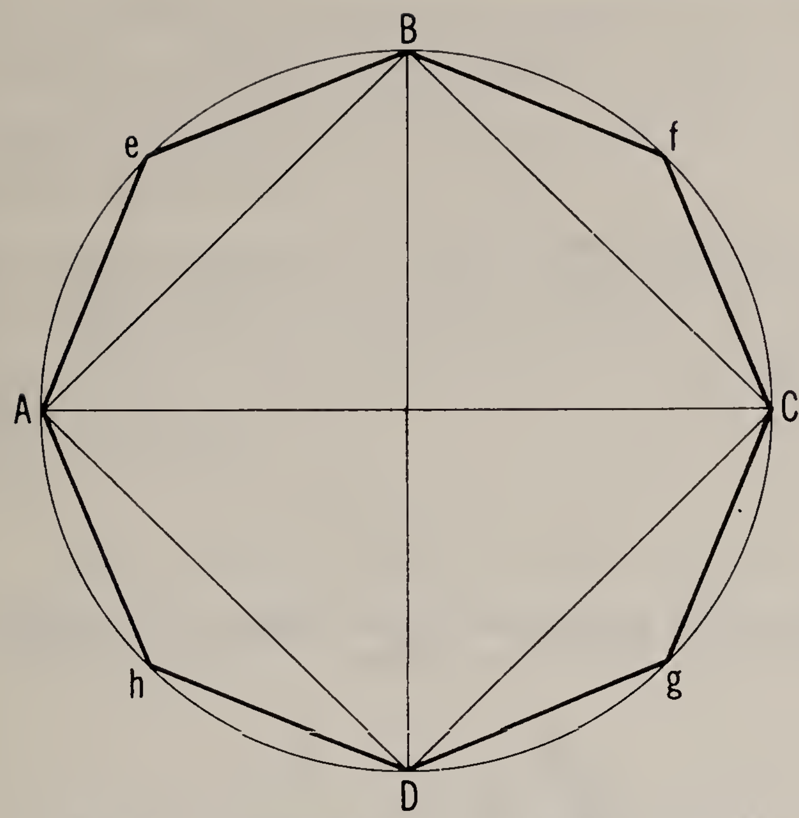


Fig. 42. To inscribe an octagon in a circle.

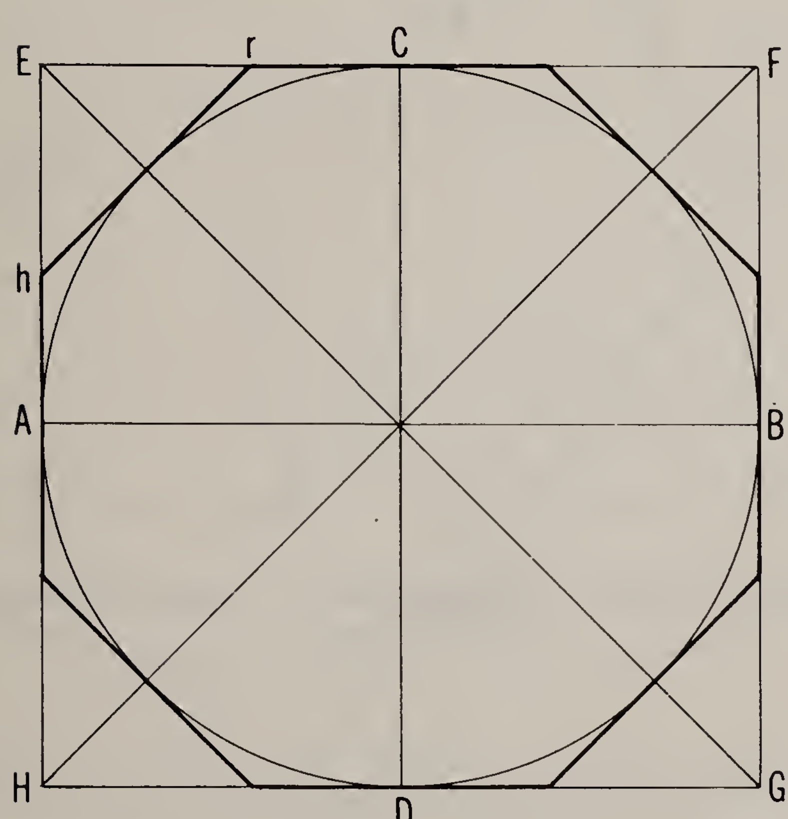


Fig. 43. To circumscribe an octagon about a circle.

2. Measurement of surfaces (areas).
   a. Two dimensions—length and width.
3. Measurement of solids (volumes).
   a. Three dimensions—length, width, and thickness.

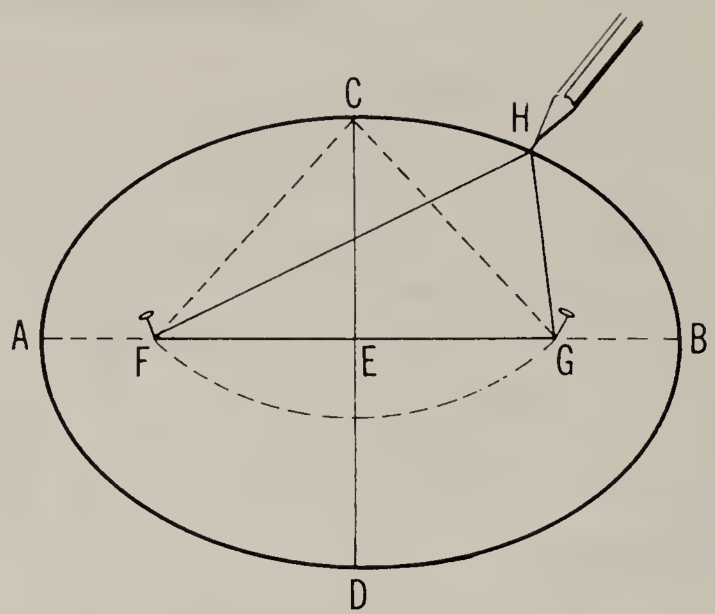


Fig. 44. To describe an ellipse when the two axes are given.

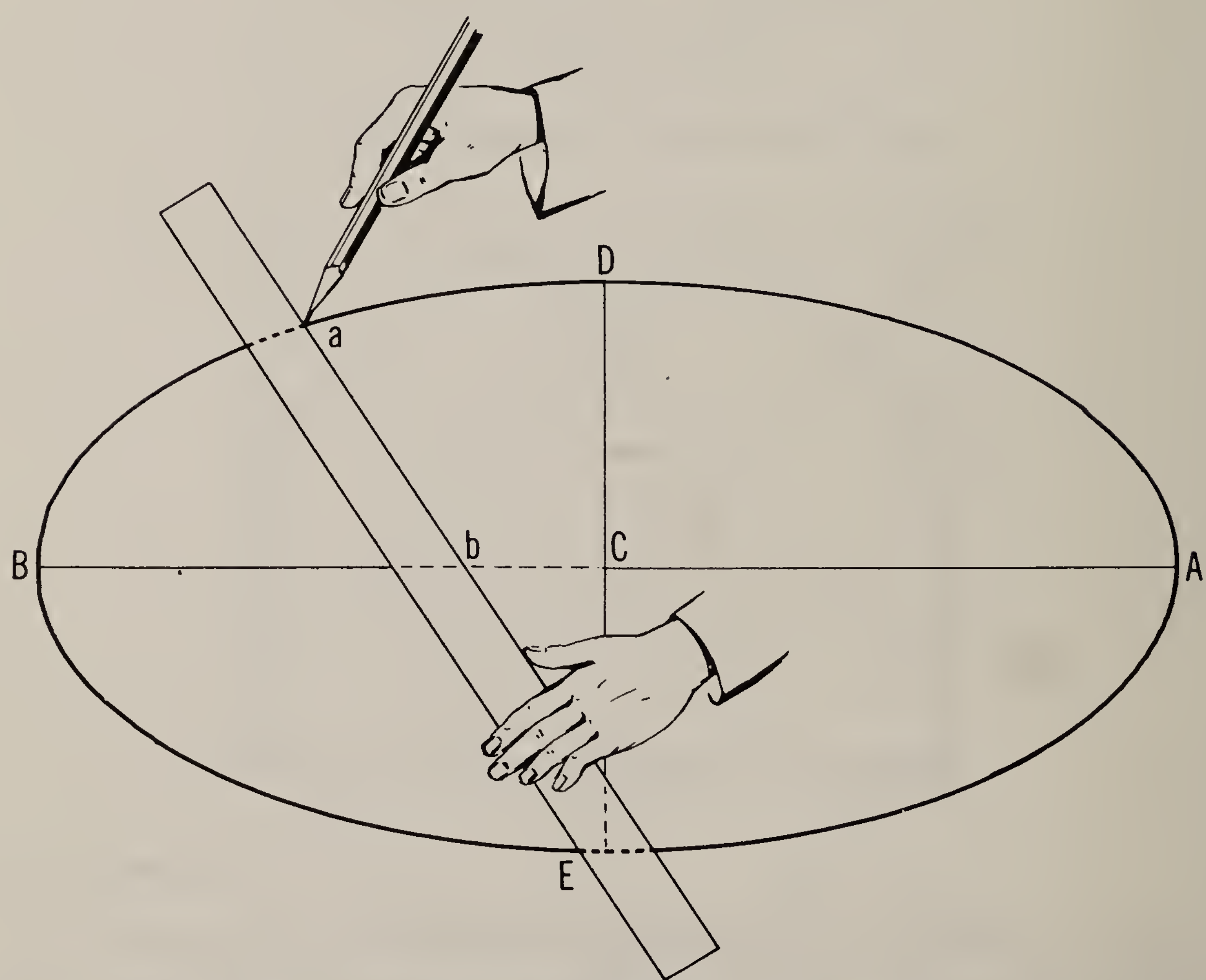


Fig. 45. To describe an ellipse given the two axes, second method.

Measurement of Lines—Length.

Problem 1—To find the length of any side of a right triangle given the other two sides.

Rule: The length of the hypotenuse equals the square root of the sum of the squares of the two legs; the length of either leg equals the square root of the difference of the square of the hypotenuse and the square of the other leg.

Example—The two legs of a right triangle measure 3 feet and 4 feet. Find the length of the hypotenuse. If the length of the hypotenuse and one leg are 5 feet and 4 feet, respectively, what is the length of the other leg?

In Fig. 46A,

$$AB = \sqrt{3^2 + 4^2} = \sqrt{25} = 5 \text{ feet}$$

In Fig. 46B, $BC = \sqrt{5^2 - 3^2} = \sqrt{25 - 9} = \sqrt{16} = 4 \text{ feet}$

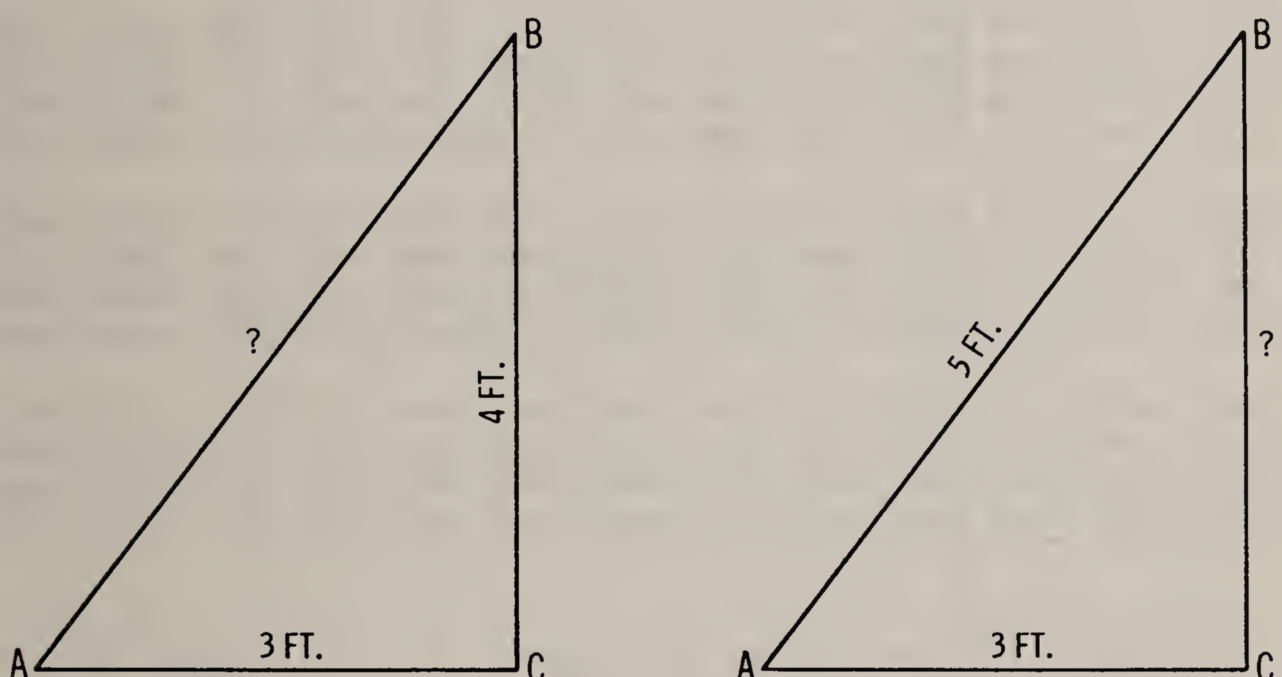


Fig. 46. To find the length of any side of a right triangle given the other two sides.

Problem 2—To find the length of the circumference of a circle.

Rule: Multiply the diameter by 3.1416.

Example—What length of moulding strip is required for a circular window which is 5 feet in diameter?

$$5 \times 3.1416 = 15.7 \text{ feet}$$

Since the carpenter does not ordinarily measure feet in tenths, .7 should be reduced to inches; it corresponds to 8-1/2 inches from Table 3. That is, the length of moulding required is 15 feet 8-1/2 inches.

Problem 3—To find the length of the arc of a circle.
Rule: Arc = .017453 × radius × central angle.

Table 3. Decimals of a Foot and Inches

Inch	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
0	.0000	.0833	.1677	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1-16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1-8	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
3-16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
1-4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5-16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3-8	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
7-16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
1-2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9-16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
5-8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
11-16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3-4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
13-16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
7-8	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
15-16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948

Example—If the radius of a circle is 2 feet, what is the length of a 60° arc?
Solution:
2 × .017453 × 60 = 2.094, or approximately 2 feet 1-1/8 inches

Problem 4—To find the rise of an arc.
Rule:

$$\textit{Rise of an arc} = \sqrt{(4 \times \textit{radius}^2) - \textit{length}}$$

Example—If the radius of a circle is 2 feet, what is the rise at the center of a 2-foot chord?
Solution :

$$1/2\ \sqrt{(4 \times 2^2) - 2} = 1/2\ \sqrt{14} = 1.87 \text{ feet} = 1 \text{ foot } 10\text{-}1/2 \text{ inches}$$

Measurement of Surfaces—Area.

Problem 5—To find the area of a square.
Rule: Multiply the base by the height.

Example—What is the area of a square whose side is 5 feet (as shown in Fig. 47)?

$$5 \times 5 = 25 \text{ square feet}$$

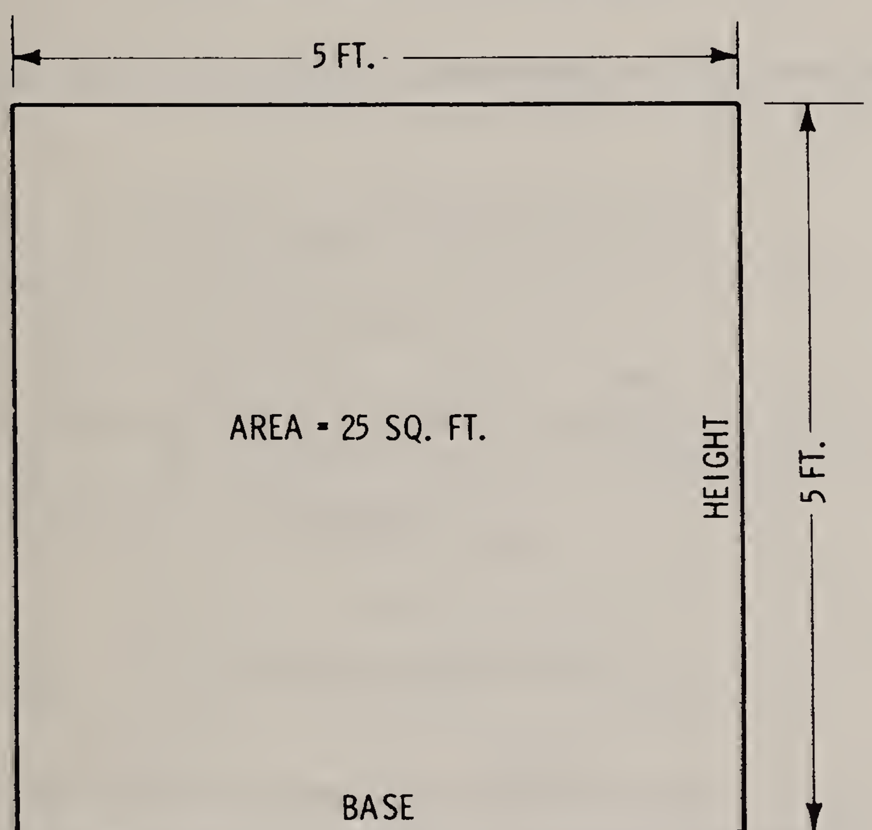


Fig. 47. To find the area of a square.

Problem 6—To find the area of a rectangle.
Rule: Multiply the base by the height (i.e., width by length).

Example—What is the floor area of a porch 5 feet wide and 12 feet long (as in Fig. 48)?

$$5 \times 12 = 60 \text{ square feet}$$

Problem 7—To find the area of a parallelogram.

Rule: Multiply the base by the perpendicular height.

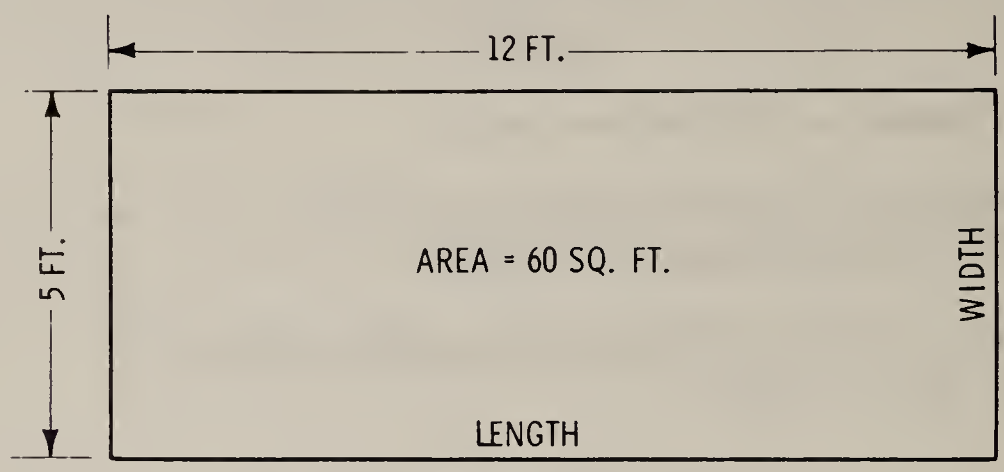


Fig. 48. To find the area of a rectangle.

Example—What is the area of the $5' \times 12'$ parallelogram shown in Fig. 49?

$$5 \times 12 = 60 \text{ square feet}$$

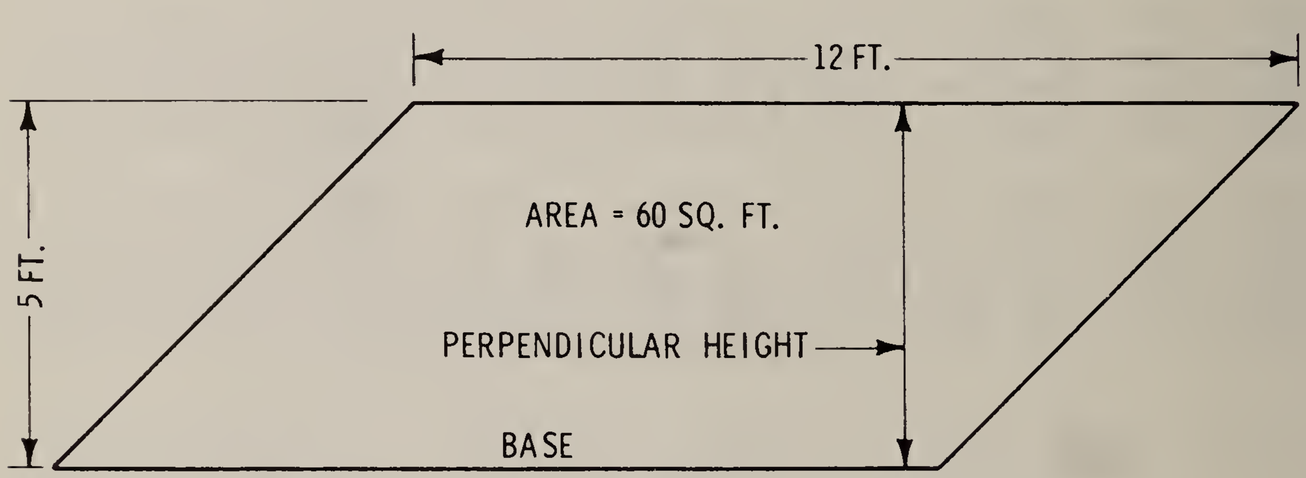


Fig. 49. To find the area of a parallelogram.

Problem 8—To find the area of a triangle.
Rule: Multiply the base by one-half the altitude.

Example—How many square feet of sheathing are required to cover a church steeple having four triangular sides (as shown in Fig. 50)?

$$1/2 \text{ altitude} = 15 \text{ feet}$$
$$\text{area of one side} = 12 \times 15 = 180 \text{ square feet}$$
$$\text{total area (four sides)} = 4 \times 180 = 720 \text{ square feet}$$

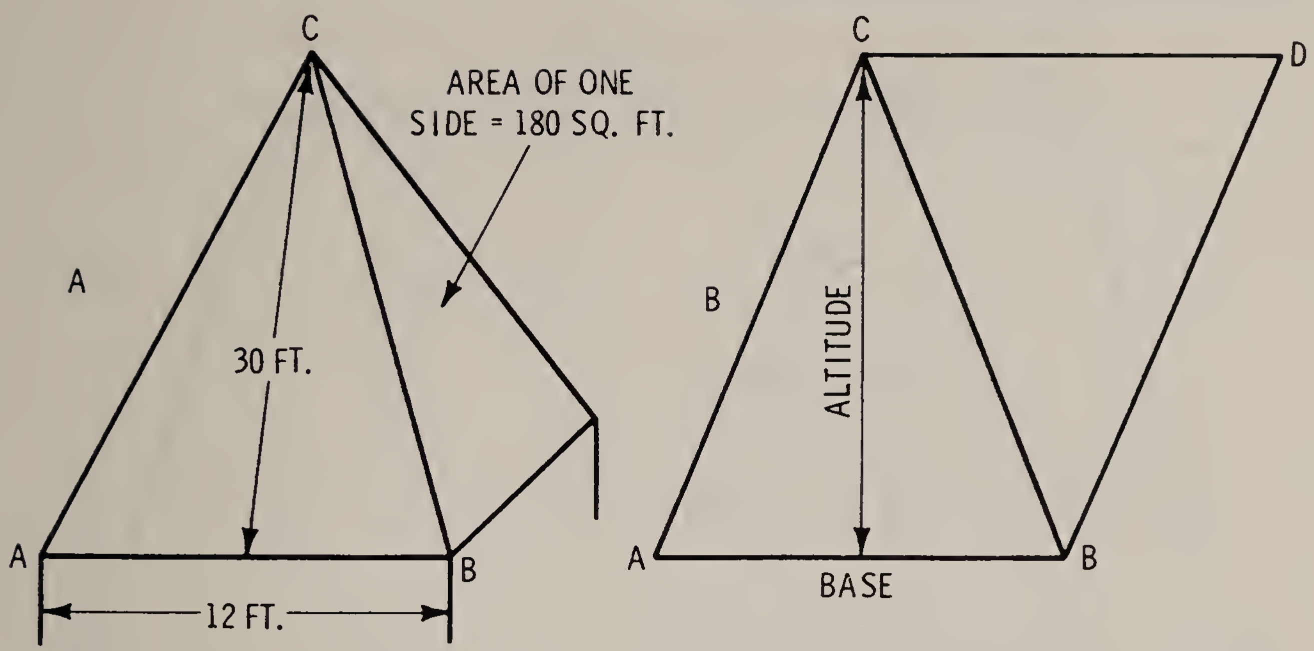


Fig. 50. To find the area of a triangle (equal to ½ area of parallelogram ABDC).

Problem 9—To find the area of a trapezoid.

Rule: Multiply one-half the sum of the two parallel sides by the perpendicular distance between them.

Example—What is the area of the trapezoid shown in Fig. 51? LA and FR are the parallel sides, and MS is the perpendicular distance between them. Therefore,

$$area = 1/2\ (LA + FR) \times MS$$

$$area = 1/2\ (8 + 12) \times 6 = 60 \text{ square feet}$$

Problem 10—To find the area of a trapezium.

Rule: Draw a diagonal, dividing the figure into triangles; measure the diagonal and the altitudes, and find the area of the triangles; the sum of these areas is then the area of the trapezium.

Example—What is the area of the trapezium shown in Fig. 52? (Draw diagonal LR and altitudes AM and FS.)

$$\text{area of triangle } ALR = 1/2\ (12 \times 9) = 54 \text{ square feet}$$

$$\text{area of triangle } LRF = 1/2\ (12 \times 6) = 36 \text{ square feet}$$

$$\text{area of trapezium } LARF = ALR + LRF = 36 + 54 = 90 \text{ sq. ft.}$$

Problem 11—To find the area of any irregular polygon.

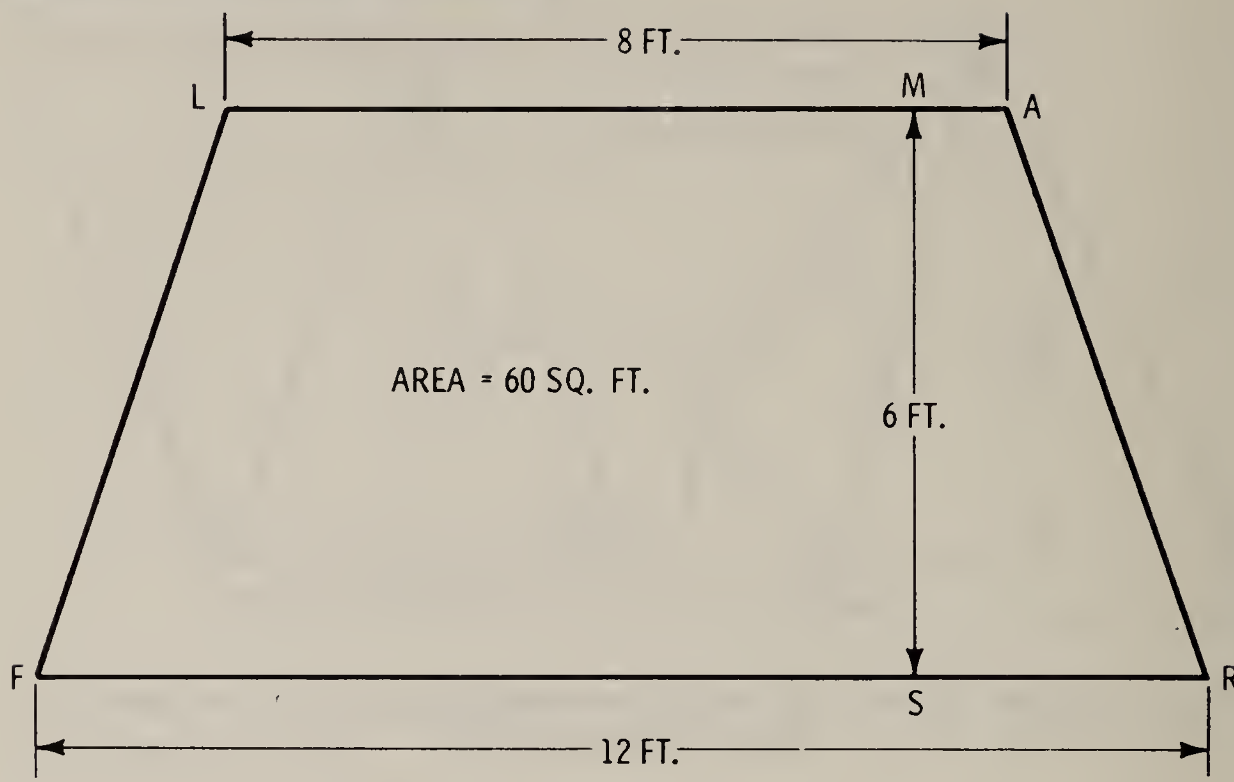


Fig. 51. To find the area of a trapezoid.

Rule: Draw diagonals, dividing the figure into triangles, and find the sum of the areas of these triangles.

Problem 12—To find the area of any regular polygon, such as shown in Fig. 53, when the length of only one side is given.

Rule: Multiply the square of the sides by the figure for "area when side = 1" opposite the particular polygon in Table 4.

Table 4. Regular Polygons

Number of sides	3	4	5	6	7	8	9	10	11	12
Area when side = 1...........	.433	1.0	1.721	2.598	3.634	4.828	6.181	7.694	9.366	11.196

Example—What is the area of an octagon (8-sided polygon) whose sides are 4 feet in length?

In Table 4 under 8 find 4.828. Multiply this by the square of one side.

$$4.828 \times 4^2 = 77.25 \text{ square feet}$$

Problem 13—To find the area of a circle.

Rule: Multiply the square of the diameter by .7854.

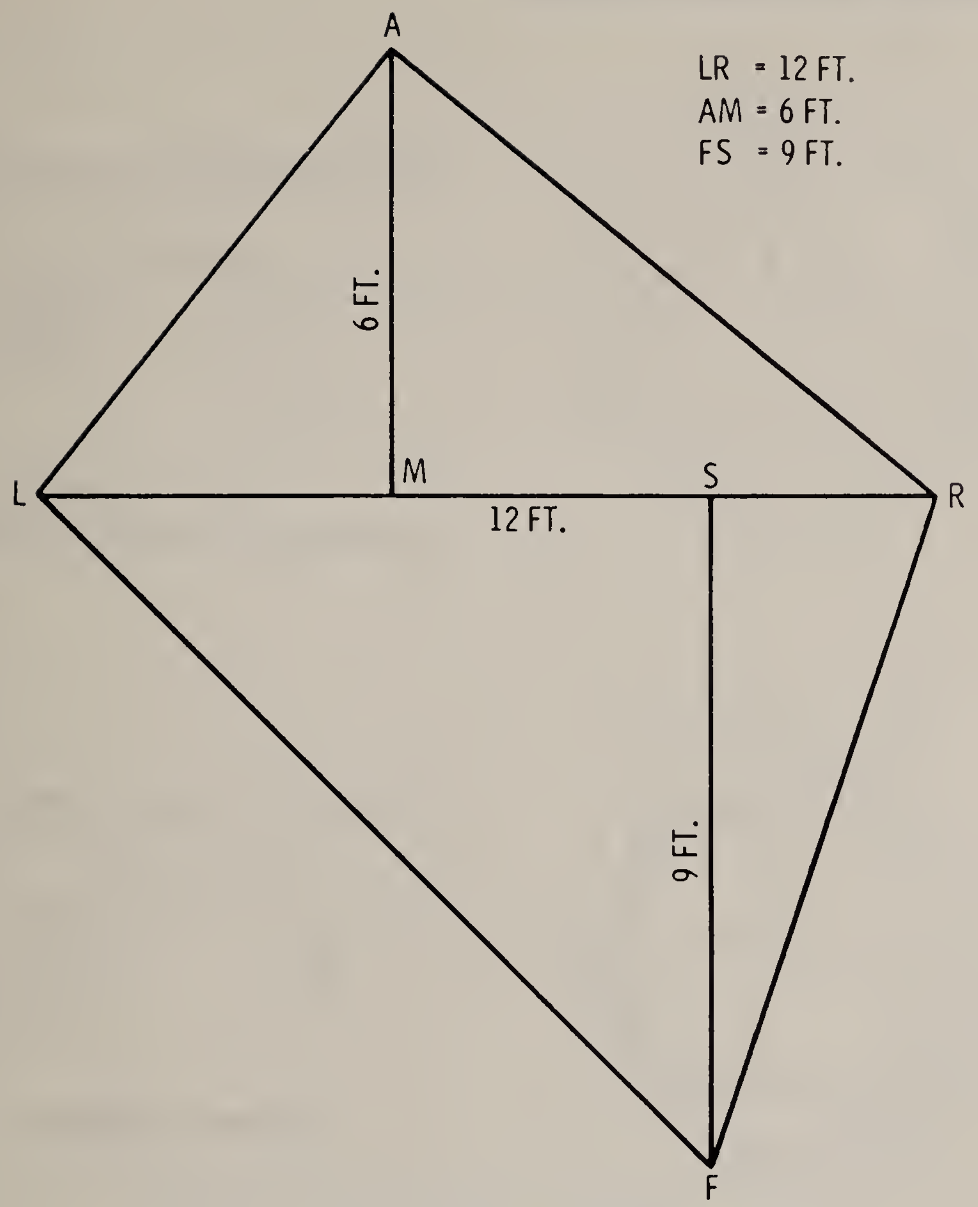


Fig. 52. To find the area of a trapezium.

Example—How many square feet of floor surface are there in a 10 foot circular floor?

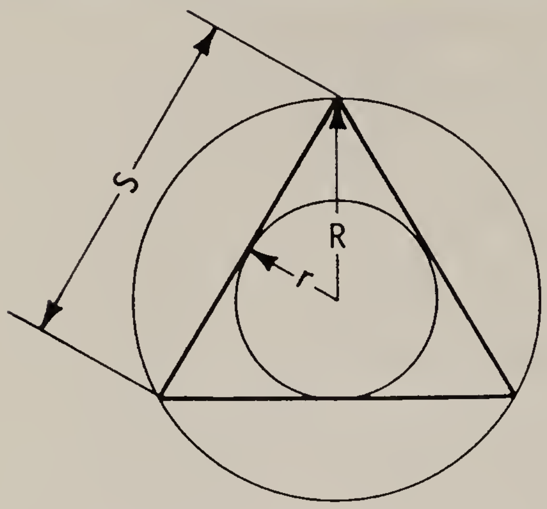
$$10^2 \times .7854 = 78.54 \text{ square feet}$$

Problem 14—To find the area of a sector of a circle.
Rule: Multiply the arc of the sector by one-half the radius.

Example—How much tin is required to cover a 60° section of a 10-foot circular deck?

$$\text{length of } 60° \text{ arc} = \frac{60}{360} \text{ of } 3.1416 \times 10 = 5.24 \text{ feet}$$

$$\text{tin required for } 60° \text{ sector} = 5.24 \times 1/2 \times 5 = 13.1 \text{ square feet}$$



A

Steel square cut to miter sides at 30^0

$R = 2r$, or $.577\ S$

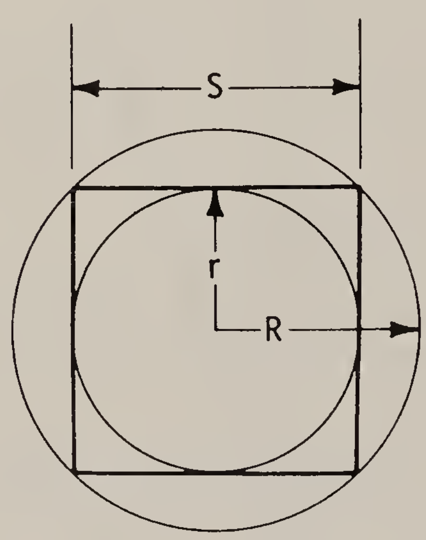
AREA $= .433\ S^2$

$= 1.299\ R^2$

$= 5.196\ r^2$

$= \dfrac{(R + r)\ S}{2}$

A. Equilateral triangle (3 sides).



B

Steel square cut to miter sides at 45^0

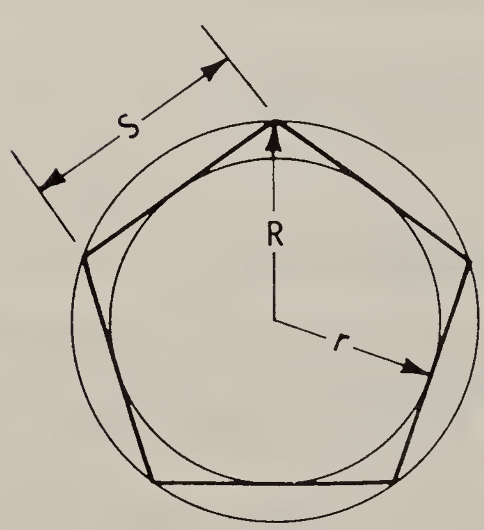
$R = .707\ S$, or $1.414\ r$

AREA $= S^2$

$= 2R^2$

$= 4r^2$

B. Square (4 sides).



C

Steel square cut to miter sides at 36^0

$R = .851\ S$, or $1.236\ r$

AREA $= 1.72\ S^2$

$= 2.378\ R^2$

$= 3.633\ r^2$

C. Pentagon (5 sides).

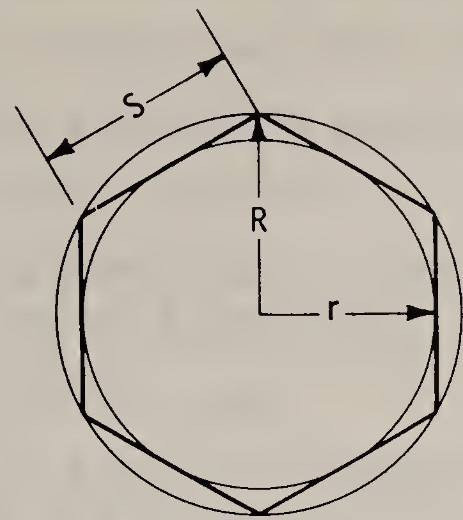
Fig. 53. Regular

Problem 15—To find the area of a segment of a circle.

Rule: Find the area of the sector which has the same arc, and also find the area of the triangle formed by the radii and chord;

Steel square cut to miter sides at 30^{0}

R = S, or 1.155 r
AREA = 2.598 S^2
= 2.598 R^2
= 3.464 r^2

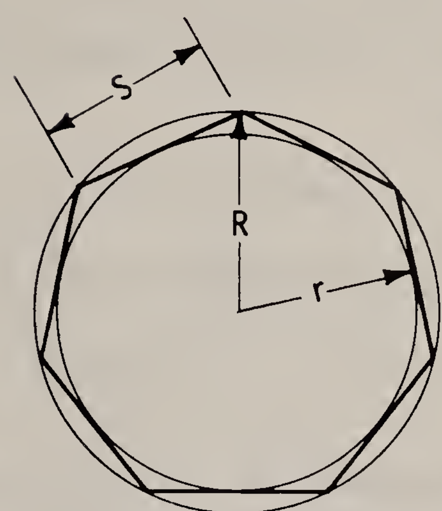


D

D. Hexagon (6 sides).

Steel square cut to miter corners at 25^{0} 43'

R = 1.152 S, or 1.11 r
AREA = 3.634 S^2
= 2.736 R^2
= 3.371 r^2

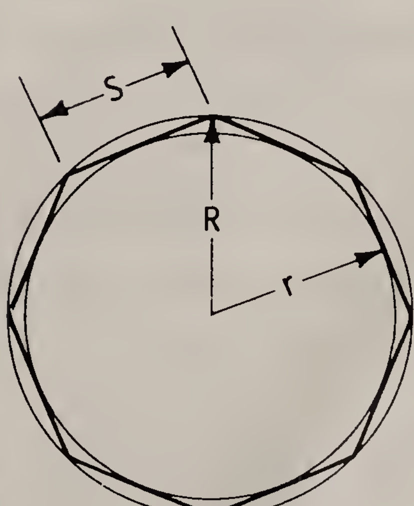


E

E. Heptagon (7 sides).

Steel square cut to miter corners at 22^{0} 30'

R = 1.307S or 1.082 r
AREA = 4.828 S^2
= 2.828 R^2
= 3.314 r^2



F

F. Octagon (8 sides).

polygons.

take the sum of these areas if the segment is greater than 180°; take the difference if the segment is less than 180°.

Problem 16—To find the area of a ring.

Rule: Take the difference between the areas of the two circles.

Problem 17—To find the area of an ellipse.
Rule: Multiply the product of the two diameters by .7854.

Example—What is the area of an ellipse whose two diameters are 10 inches and 6 inches?

$$10 \times 6 \times .7854 = 47.12 \textit{ square inches}$$

Problem 18—To find the circular area of a cylinder.
Rule: Multiply 3.1416 by the diameter and by the height.

Example—How many square feet of lumber are required for the sides of a cylindrical tank (Fig. 55) which is 8 feet in diameter and 12 feet high? How many 4″ × 12′ pieces will be required?

$$\textit{cylindrical surface} = 3.1416 \times 8 \times 12 = 302 \textit{ square feet}$$

$$\textit{circumference of tank} = 3.1416 \times 8 = 25.1 \textit{ feet}$$

$$\textit{number of } 4'' \times 12' \textit{ pieces} = \frac{25.1 \times 12}{4} = 25.1 \times 3 = 75.3$$

Problem 19—To find the area of a cone.
Rule: Multiply 3.1416 by the diameter of the base and by one-half the slant height.

Example—A conical spire with a base 10 feet in diameter and an altitude of 20 feet is to be covered. Find the area of the surface to be covered.

$$\textit{slant height} = \sqrt{5^2 + 20^2} = \sqrt{425} = 20.62 \textit{ feet}$$

$$\textit{circumference of base} = 3.1416 \times 10 = 31.416 \textit{ feet}$$

$$\textit{area of conical surface} = 31.416 \times 1/2 \times 20.62 = 324 \text{ square ft.}$$

Problem 20—To find the area of the frustum of a cone.
Rule: Multiply one-half the slant height by the sum of the circumference.

Example—A tank is 12 feet in diameter at the base, 10 feet at the top, and 8 feet high. What is the area of the slant surface?

$$\text{circumference of 10-foot diameter} = 3.1416 \times 10 = 31.416 \text{ feet}$$

circumference of 12-foot diameter $= 3.1416 \times 12 = 37.7$ feet

sum of circumferences $= 69.1$ feet

slant height $= \sqrt{1^2 + 8^2} = \sqrt{65} = 8.12$

slant surface $=$ sum of circumferences $\times$ 1/2 slant height

slant surface $= 69.1 \times 1/2 \times 8.12 = 280$ square feet

Measurement of Solids—Volume

Problem 21—To find the volume of a rectangular solid. *Rule:* Multiply the length, width, and thickness together.

Example—What is the volume of a $4'' \times 8'' \times 12'$ timber? (Before applying the rule, reduce all dimensions to feet.)

$$4'' = 1/3 \text{ foot}$$

$$8'' = 2/3 \text{ foot}$$

$$\text{volume of timber} = 1/3 \times 2/3 \times 12 = 2.67 \text{ cubic feet}$$

If the timber were a piece of oak weighing 48 pounds per cubic foot, the total weight would be

$$48 \times 2.67 = 128 \text{ pounds}$$

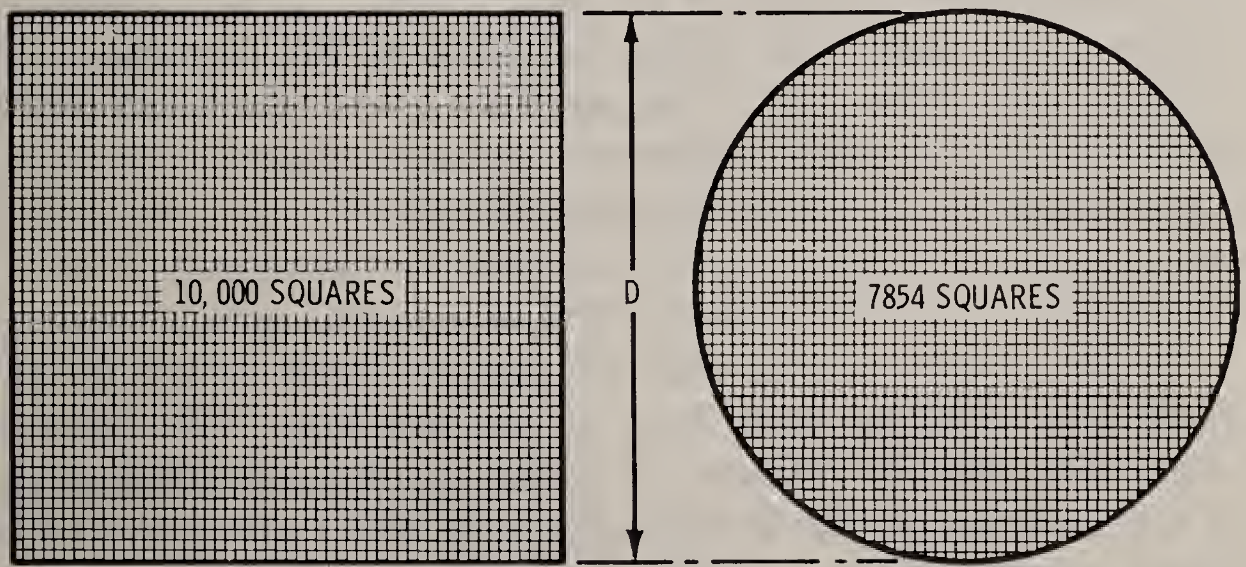


Fig. 54. The decimal .7854 is used to find the area of a circle. If a square is divided into 10,000 equal parts (small squares), then a circle with a diameter D equal to one side of the large square will contain 7854 small squares; therefore, if the area of the large square is 1 square inch, then the area of the circle will be 7854/10,000, or .7854 square inch.

Problem 22—To find the volume of a rectangular wedge.

Rule: Find the area of one of the triangular ends, and multiply the area by the distance between the ends.

Example—An attic has the shape of a rectangular wedge. What volume storage capacity would there be for the proportions shown in Fig. 58? In the illustration, the boundary of the attic is LARFMS.

area of triangular end MLA $= 20 \times 10/2 = 100$ square feet

volume of attic $= 100 \times 40 = 4000$ cubic feet

TRIGONOMETRY

Trigonometry is that branch of mathematics which deals with the relations that exist between the sides and angles of triangles, and more especially with those of the methods of calculating the required parts of triangles from given parts. The only branch of trigonometry useful to the carpenter and builder is plane trigonometry, where the lines in the triangles are straight and where they all lie in the same plane.

There are six elements, or parts, in every triangle—three sides and three angles. The sum of the three angles, no matter what the lengths of the sides, will always be equal to 180 degrees.

When any three of the six parts are given, provided one or more of them are sides, the other three are calculable. The angles are measured in circular measure—in degrees (°), minutes (′), and seconds (″). The term *degree* has no numerical value; in trigonometry it simply means 1/360 of a circle, nothing more.

To the student of trigonometry, any two radii which divide a circle into anything more than 0° or less than 360° form an angle. The first 90° division is called the *first quadrant.* Angles in this quadrant are the *acute angles* (Fig. 59A) mentioned earlier in this chapter. Angles from 90° to 180° are in the *second quadrant.* These are the *obtuse angles* (Fig. 59B) mentioned. Angles from 180° to 270° lie in the *third quadrant,* and angles from 270° to 360° lie in the *fourth quadrant.* These quadrants are represented pictorially in Fig. 60. Only angles in the first and second

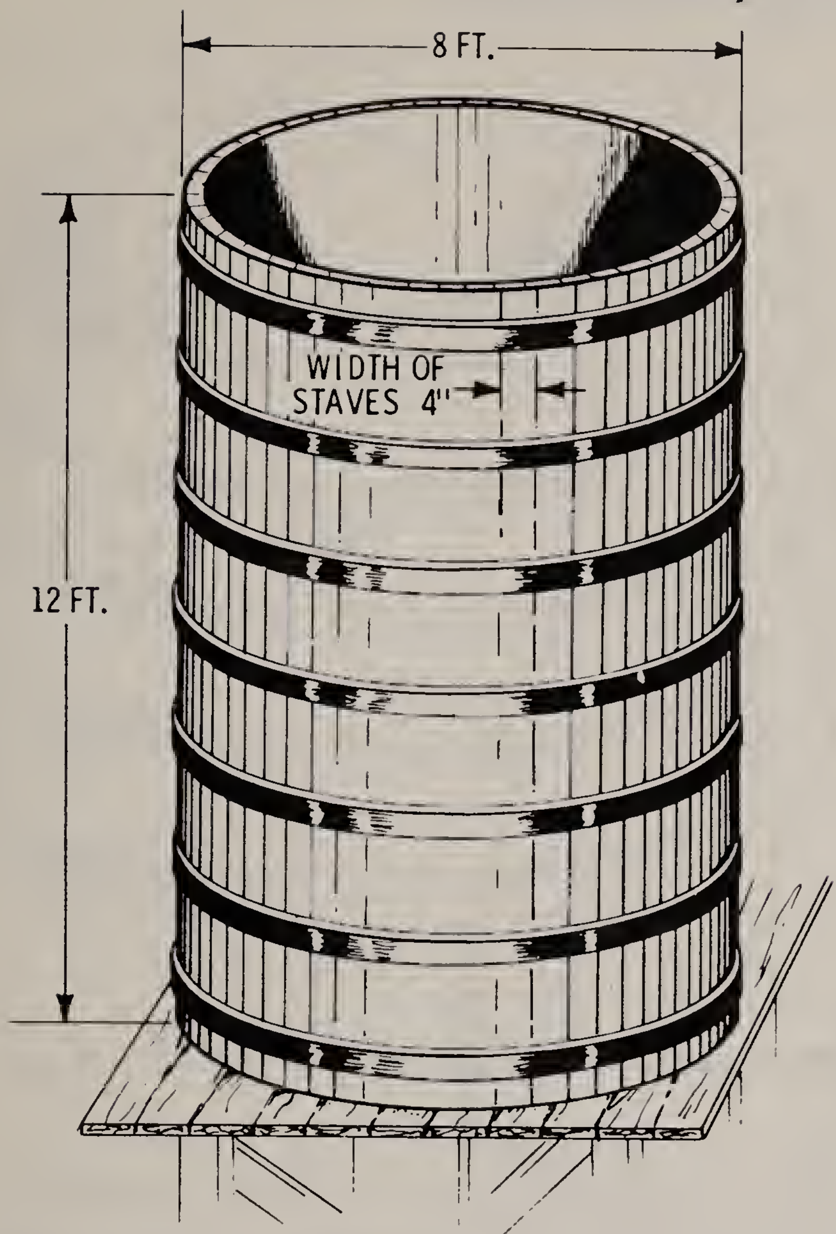


Fig. 55. To find the area of a cylinder.

quadrants, from 0° to 180°, will be discussed in this section. Note that a straight line may be considered as an angle of 180°. Trigonometry is actually based on geometry, but it makes use of many algebraic operations that can be used by carpenters and builders.

Trigonometric Functions

In mathematics, a *function* means a quantity which necessarily changes because of a change in another number with which it is connected in some way. In trigonometry, it is probably less confusing to call the trigonometric functions simply *ratios,* which they truly are.

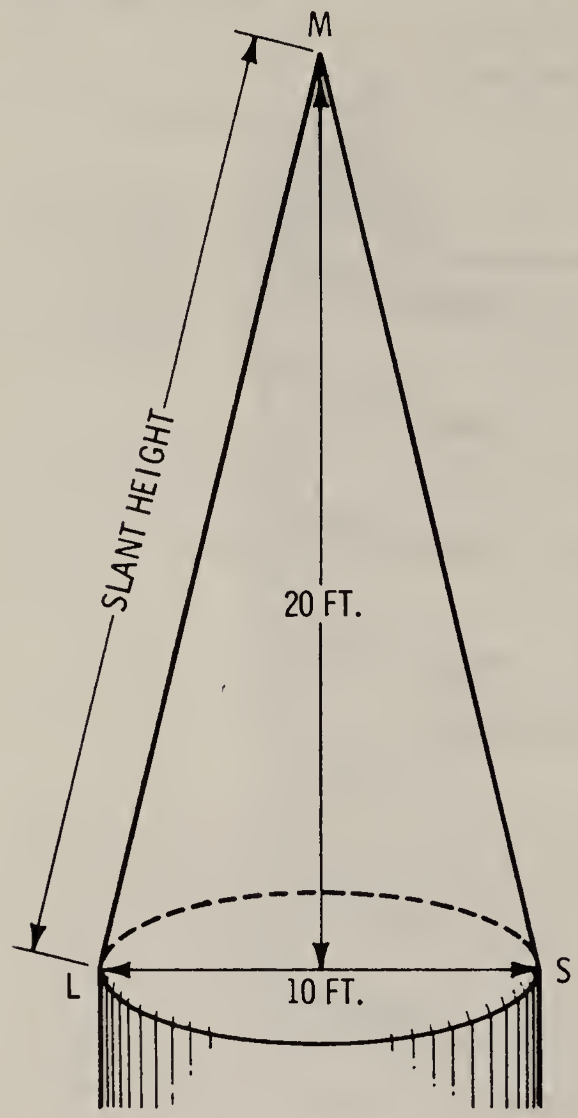


Fig. 56. To find the surface area of a cone.

Refer to Fig. 61 for an explanation of the following. There are six trigonometric ratios which are commonly used:

$$\text{Sine of angle A} = \frac{\text{opposite side}}{\text{hypotenuse}} \text{ or } \frac{BC}{AB}$$

$$\text{Cosine of angle A} = \frac{\text{adjacent side}}{\text{hypotenuse}} \text{ or } \frac{AC}{AB}$$

$$\text{Tangent of angle A} = \frac{\text{opposite side}}{\text{adjacent side}} \text{ or } \frac{BC}{AC}$$

$$\text{Cotangent of angle A} = \frac{\text{adjacent side}}{\text{opposite side}} \text{ or } \frac{AC}{BC}$$

$$\text{Secant of angle A} = \frac{\text{hypotenuse}}{\text{adjacent side}} \text{ or } \frac{AB}{AC}$$

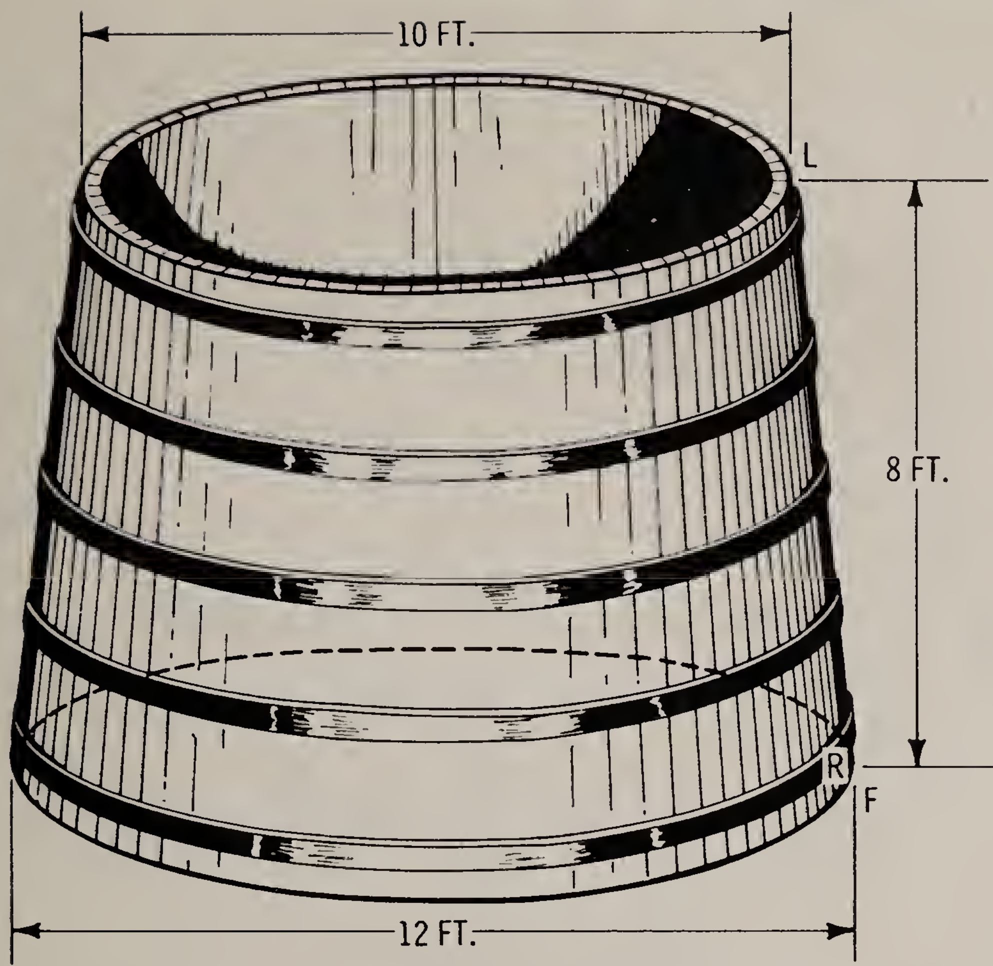


Fig. 57. To find the area of the frustum of a cone.

$$\text{Cosecant of angle A} = \frac{\text{hypotenuse}}{\text{opposite side}} \text{ or } \frac{AB}{BC}$$

Note that these last three functions are only *reciprocals* of the sine, cosine, and tangent, respectively, or

$$\text{cosecant} = \frac{1}{\text{sine}}$$

$$\text{secant} = \frac{1}{\text{cosine}}$$

$$\text{cotangent} = \frac{1}{\text{tangent}}$$

If a proposition calls for multiplication by the sine of an angle, the same result will be obtained by dividing by the cosecant. It is convenient to do this in many calculations.

It is impossible in a discussion of this type to give a comprehensive table of the trigonometric ratios, although an adequate

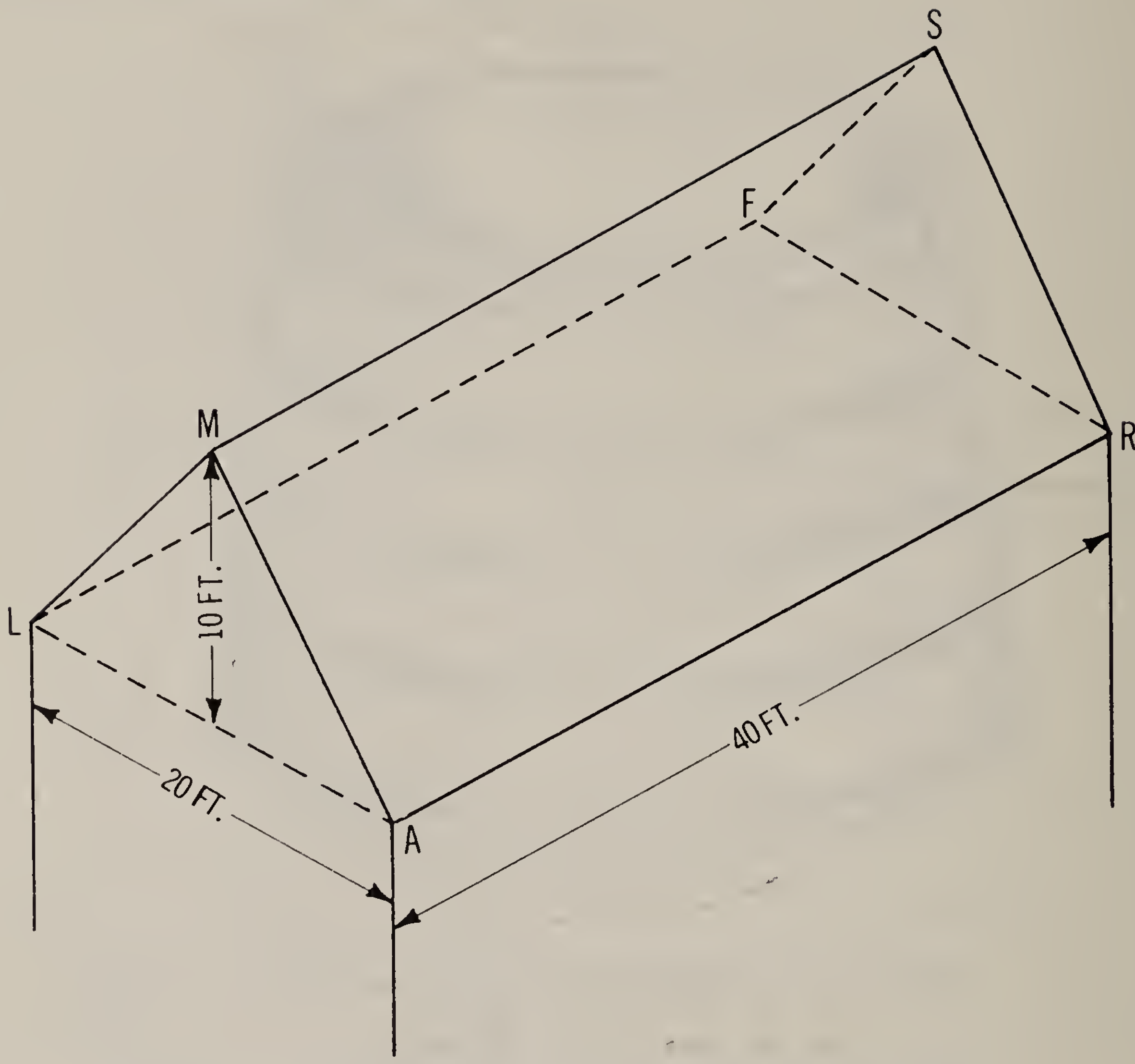
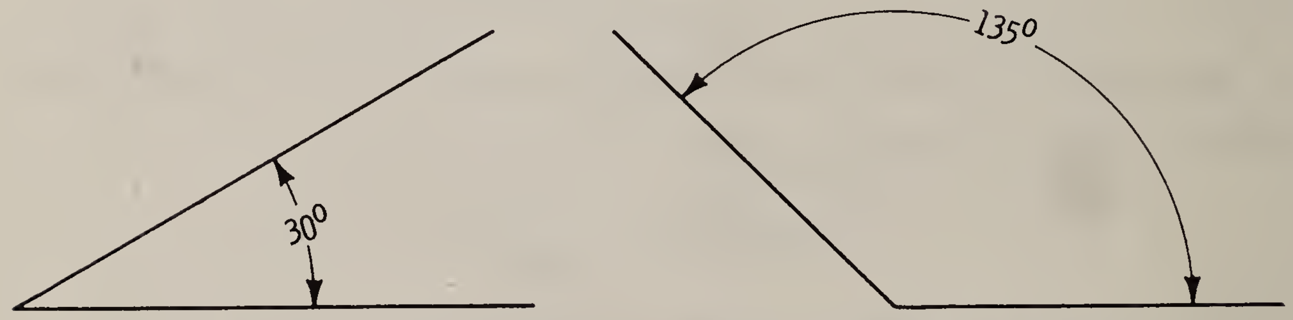


Fig. 58. To find the volume of a rectangular wedge.



A. An angle in the first quadrant is an acute angle.

B. An angle in the second quadrant is an obtuse angle.

Fig. 59. Acute and obtuse angles.

but limited number of trigonometric functions are presented in Table 5. If the student expects to follow up the information given here, however, he is advised to procure a book of five- or six-place tables.

As an example of how trigonometric ratios are used to solve one of the carpenter's most common problems, determining the

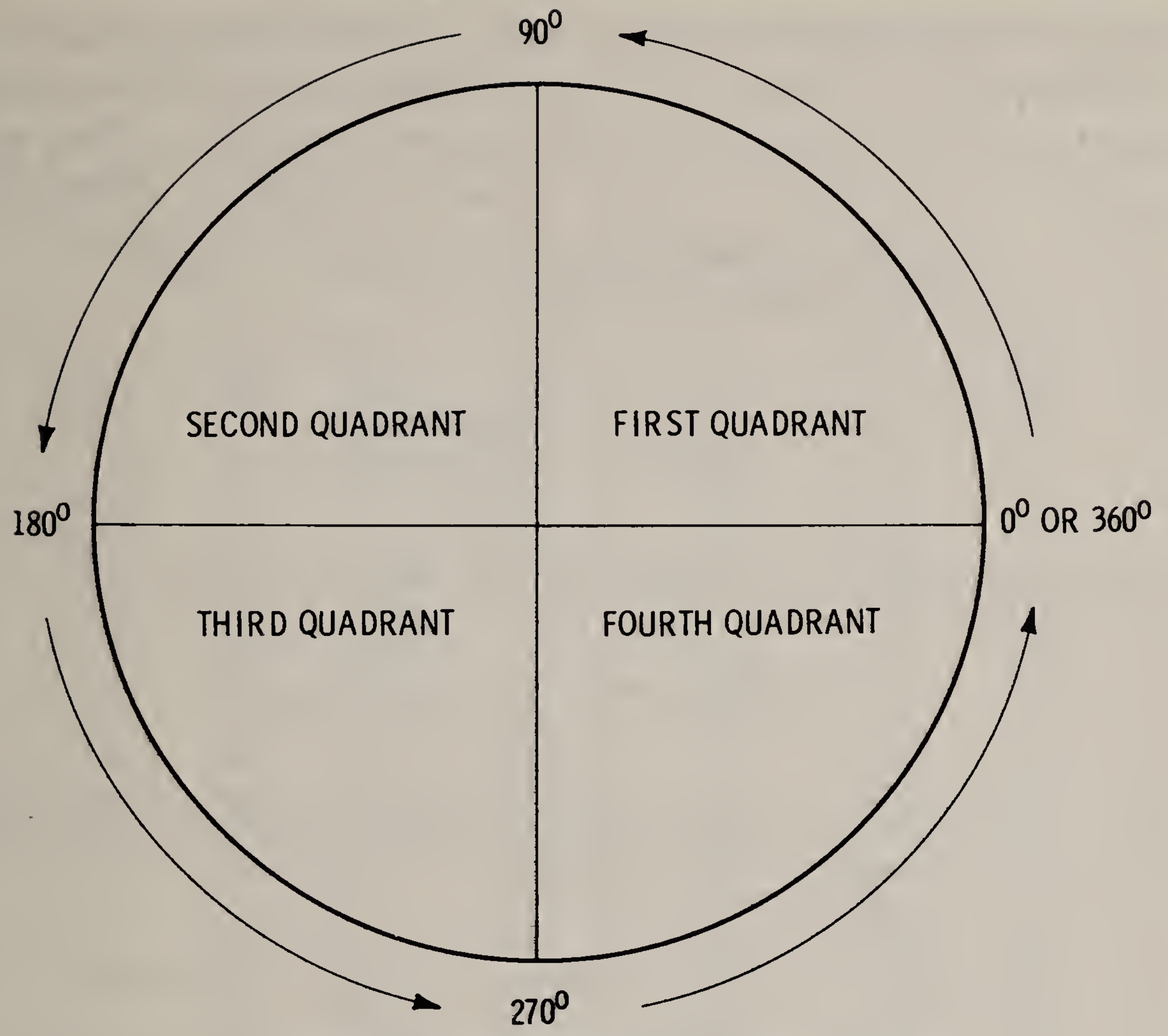


Fig. 60. The four quadrants of a circle.

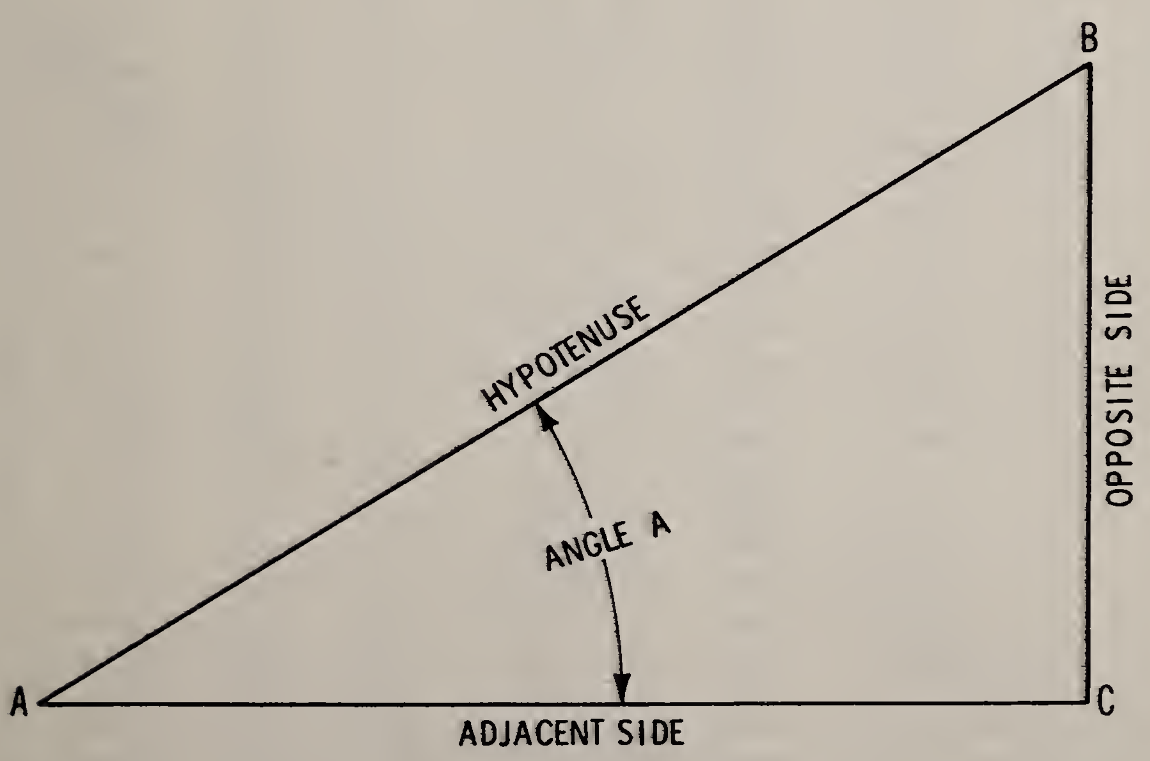


Fig. 61. A right triangle illustrates the application of trigonometric ratios which are commonly used.

length of rafters given the rise and run, refer to Fig. 62. The slope of the roof, in degrees, may be determined by dividing the opposite side 12 feet, by the adjacent side, 18 feet. This is the tangent of the angle A and is equal to 12/18, or .6667. From Table 5, angle A is determined to be 33° 42′. The length of the rafter may be determined by the ratio:

$$\text{secant} = \frac{\text{hypotenuse}}{\text{adjacent side}}$$

or the hypotenuse (the length of the rafter) is equal to

$$\textit{secant } 33°42' \times \textit{adjacent side}$$

The secant of 33°42′ is equal to 1.2020. Therefore, the calculation for the length of the rafter is

$$1.2020 \times 18 = 21.64 \textit{ feet} = 21 \textit{ feet } 7\text{-}3/16 \textit{ inches}$$

Since the opposite side is known to be 12 feet, the calculation could just as easily be made by using the cosecant function.

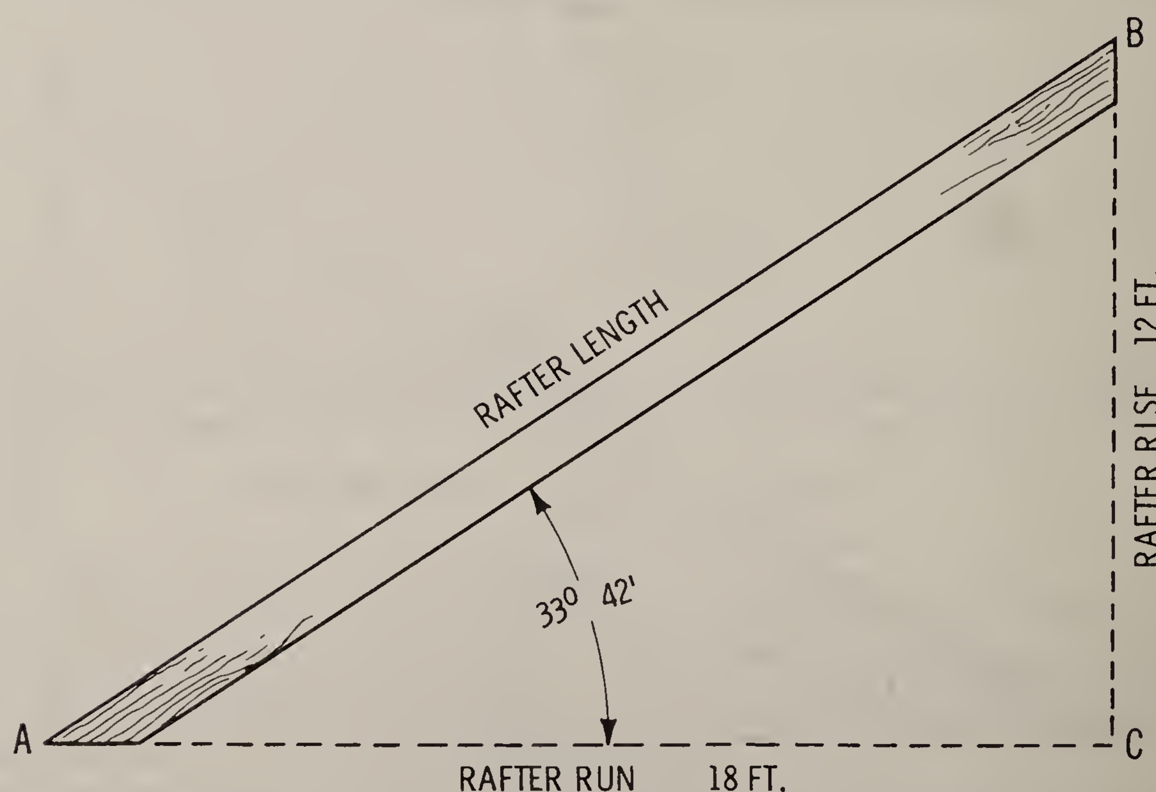


Fig. 62. Trigonometric ratios may be used to determine the lengths of rafters for a roof.

The slopes, in degrees, for all regular roof pitches are given in Table 6; these pitches range from 12×1 to 12×12, and the three main trigonometric ratios—sine, cosine, and tangent—are provided for each pitch.

Table 5. Natural Trigonometric Functions

Degree	Sine	Cosine	Tangent	Secant	Degree	Sine	Cosine	Tangent	Secant
0	.00000	1.0000	.00000	1.0999	46	.7193	.6947	1.0355	1.4395
1	.01745	.9998	.01745	1.0001	47	.7314	.6820	1.0724	1.4663
2	.03490	.9994	.03492	1.0006	48	.7431	.6691	1.1106	1.4945
3	.05234	.9986	.05241	1.0014	49	.7547	.6561	1.1504	1.5242
4	.06976	.9976	.06993	1.0024	50	.7660	.6428	1.1918	1.5557
5	.08716	.9962	.08749	1.0038	51	.7771	.6293	1.2349	1.5890
6	.10453	.9945	.10510	1.0055	52	.7880	.6157	1.2799	1.6243
7	.12187	.9925	.12278	1.0075	53	.7986	.6018	1.3270	1.6616
8	.1392	.9903	.1405	1.0098	54	.8090	.5878	1.3764	1.7013
9	.1564	.9877	.1584	1.0125	55	.8192	.5736	1.4281	1.7434
10	.1736	.9848	.1763	1.0154	56	.8290	.5592	1.4826	1.7883
11	.1908	.9816	.1944	1.0187	57	.8387	.5446	1.5399	1.8361
12	.2079	.9781	.2126	1.0223	58	.8480	.5299	1.6003	1.8871
13	.2250	.9744	.2309	1.0263	59	.8572	.5150	1.6643	1.9416
14	.2419	.9703	.2493	1.0306	60	.8660	.5000	1.7321	2.0000
15	.2588	.9659	.2679	1.0353	61	.8746	.4848	1.8040	2.0627
16	.2756	.9613	.2867	1.0403	62	.8829	.4695	1.8807	2.1300
17	.2924	.9563	.3057	1.0457	63	.8910	.4540	1.9626	2.2027
18	.3090	.9511	.3249	1.0515	64	.8988	.4384	2.0503	2.2812
19	.3256	.9455	.3443	1.0576	65	.9063	.4226	2.1445	2.3662
20	.3420	.9397	.3640	1.0642	66	.9135	.4067	2.2460	2.4586
21	.3584	.9336	.3839	1.0711	67	.9205	.3907	2.3559	2.5598
22	.3746	.9272	.4040	.1.0785	68	.9272	.3746	2.4751	2.6695
23	.3907	.9205	.4245	1.0864	69	.9336	.3584	2.6051	2.7904
24	.4067	.9135	.4452	1.0946	70	.9397	.3420	2.7475	2.9238
25	.4226	.9063	.4663	1.1034	71	.9455	.3256	2.9042	3.0715
26	.4384	.8988	.4877	1.1126	72	.9511	.3090	3.0777	3.2361
27	.4540	.8910	.5095	1.1223	73	.9563	.2924	3.2709	3.4203
28	.4695	.8829	.5317	1.1326	74	.9613	.2756	3.4874	3.6279
29	.4848	.8746	.5543	1.1433	75	.9659	.2588	3.7321	3.8637
30	.5000	.8660	.5774	1.1547	76	.9703	.2419	4.0108	4.1336
31	.5150	.8572	.6009	1.1663	77	.9744	.2250	4.3315	4.4454
32	.5299	.8480	.6249	1.1792	78	.9781	.2079	4.7046	4.8097
33	.5446	.8387	.6494	1.1924	79	.9816	.1908	5.1446	5.2408
34	.5592	.8290	.6745	1.2062	80	.9848	.1736	5.6713	5.7588
35	.5736	.8192	.7002	1.2208	81	.9877	.1564	6.3138	6.3924
36	.5878	.8090	.7265	1.2361	82	.9903	.1392	7.1154	7.1853
37	.6018	.7986	.7536	1.2521	83	.9925	.12187	8.1443	8.2055
38	.6157	.7880	.7813	1.2690	84	.9945	.10453	9.5144	9.5668
39	.6293	.7771	.8098	1.2867	85	.9962	.08716	11.4301	11.474
40	.6428	.7660	.8391	1.3054	86	.9976	.06976	14.3007	14.335
41	.6561	.7547	.8693	1.3250	87	.9986	.05234	19.0811	19.107
42	.6691	.7431	.9004	1.3456	88	.9994	.03490	28.6363	28.654
43	.6820	.7314	.9325	1.3673	89	.9998	.01745	57.2900	57.299
44	.6947	.7193	.9657	1.3902	90	1.0000	Inf.	Inf.	Inf.
45	.7071	.7071	1.0000	1.4142		—	—	—	—

Other typical examples of how trigonometric ratios can aid carpenters are shown in the following problems.

Problem 1—A grillwork consisting of radial and vertical members is to be built in a semicircular opening with a radius of 6 feet, as shown in Fig. 63. Find the lengths of the vertical pieces MS and LF.

For triangle OMS, the hypotenuse is known to be 6 feet, and angle O is 30°. Line MS is the opposite side of the triangle, and

opposite side = 30°, or $\frac{\text{opposite side}}{\text{hypotenuse}}$ = sine 30° × hypotenuse. (sine 30° = .500). This is the calculation:

$$\text{opposite side} = .500 \times 6 = 3 \text{ feet}$$

For triangle OLF, the hypotenuse is 6 feet, and angle O is 60°. Line LF is the opposite side, and $\frac{\text{opposite side}}{\text{hypotenuse}} = 60°$,

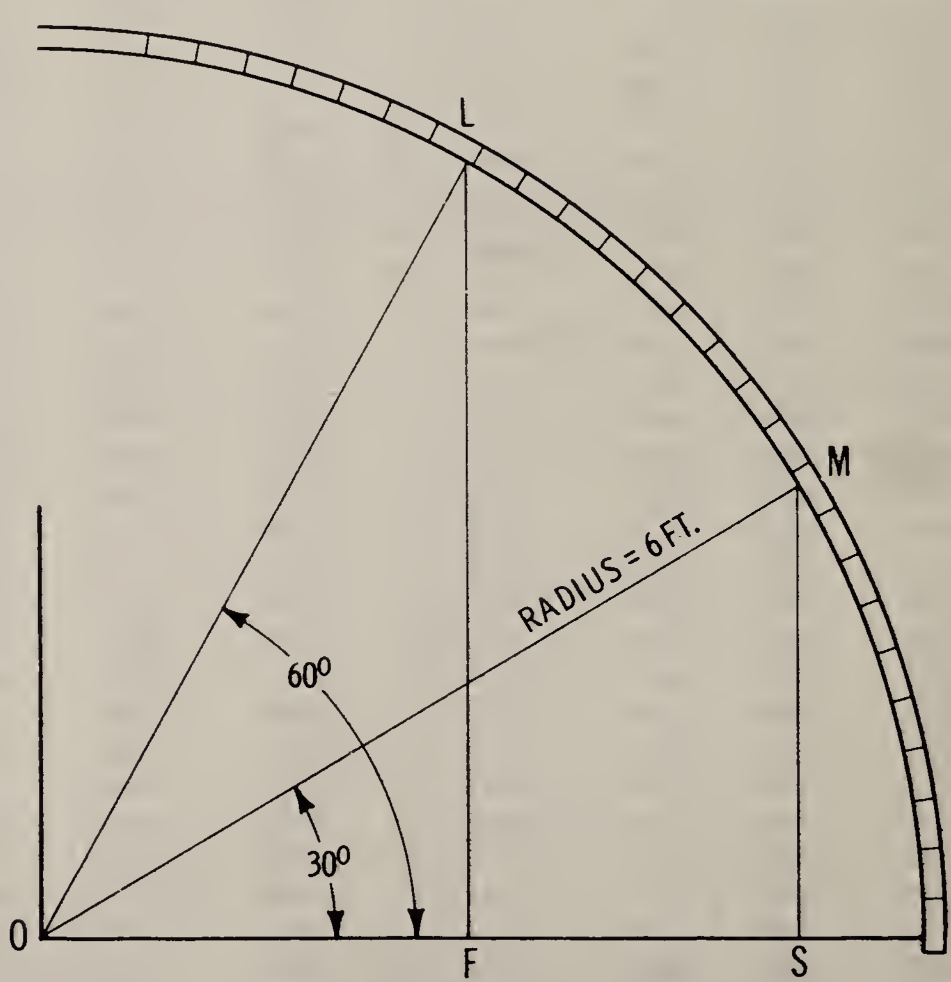


Fig. 63. The method of finding the length of vertical pieces in grillwork with the aid of trigonomtric relations.

or opposite side = sine 60° × hypotenuse. (sine 60° = .866) This is the calculation:

opposite side = .866 × 6 = 5.196 feet = 5 feet 2-3/8 inches

Problem 2—When laying out the grillwork in Fig. 63, how far must the members LF and MS be spaced from the center O to be vertical?

The hypotenuse is known to be 6 feet and the length of adjacent side OF is to be found.

$$\frac{\text{adjacent side}}{\text{hypotenuse}} = \cos 60°, \text{ or}$$

adjacent side = cos 60° × hypotenuse. (cos 60° = .500) This is the calculation:

adjacent side OF = .500 × 6 = 3 feet

For the length of the adjacent side OS, $\frac{\text{adjacent side}}{\text{hypotenuse}} = \cos 30°$,

or adjacent side = cos 30° × hypotenuse. (cos 30° = .866) This is the calculation:

adjacent side OS = .866 × 6 = 5.196 feet = 5 feet 2-3/8 inches

Table 6. Roof Pitches in Degrees and Minutes

(Measured from the horizontal)

Pitch	Sine	Cosine	Tangent
12 x 1 = 4° 46′	.083098	.996541	.083386
12 x 2 = 9° 28′	.164474	.986381	.166745
12 x 3 = 14° 2′	.242486	.970155	.249946
12 x 4 = 18° 26′	.316201	.948692	.333302
12 x 5 = 22° 37′	.384564	.923098	.416601
12 x 6 = 26° 34′	.444635	.895712	.496404
12 x 7 = 30° 15′	.503774	.863836	.583183
12 x 8 = 33° 41′	.554602	.832115	.666497
12 x 9 = 36° 53′	.600188	.799859	.750366
12 x 10 = 39° 46′	.639663	.768656	.832183
12 x 11 = 42° 31′	.675805	.737081	.916866
12 x 12 = 45° 00′	.707107	.707107	1.000000

Table 7. Functions of Numbers

No.	Square	Cube	Square Root	Cubic Root	Logarithm	1000 x Reciprocal	No. = Diameter	
							Circum.	Area
1	1	1	1.0000	1.0000	0.00000	1000.000	3.142	0.7854
2	4	8	1.4142	1.2599	0.30103	500.000	6.283	3.1416
3	9	27	1.7321	1.4422	0.47712	333.333	9.425	7.0686
4	16	64	2.0000	1.5874	0.60206	250.000	12.566	12.5664
5	25	125	2.2361	1.7100	0.69897	200.000	15.708	19.6350
6	36	216	2.4495	1.8171	0.77815	166.667	18.850	28.2743
7	49	343	2.6458	1.9129	0.84510	142.857	21.991	38.4845
8	64	512	2.8284	2.0000	0.90309	125.000	25.133	50.2655
9	81	729	3.0000	2.0801	0.95424	111.111	28.274	63.6173
10	100	1000	3.1623	2.1544	1.00000	100.000	31.416	78.5398
11	121	1331	3.3166	2.2240	1.04139	90.9091	34.558	95.0332
12	144	1728	3.4641	2.2894	1.07918	83.3333	37.699	113.097
13	169	2197	3.6056	2.3513	1.11394	76.9231	40.841	132.732
14	196	2744	3.7417	2.4101	1.14613	71.4286	43.982	153.938
15	225	3375	3.8730	2.4662	1.17609	66.6667	47.124	176.715
16	256	4096	4.0000	2.5198	1.20412	62.5000	50.265	201.062
17	289	4913	4.1231	2.5713	1.23045	58.8235	53.407	226.980
18	324	5832	4.2426	2.6207	1.25527	55.5556	56.549	254.469
19	361	6859	4.3589	2.6684	1.27875	52.6316	59.690	283.529
20	400	8000	4.4721	2.7144	1.30103	50.0000	62.832	314.159
21	441	9261	4.5826	2.7589	1.32222	47.6190	65.973	346.361
22	484	10648	4.6904	2.8020	1.34242	45.4545	69.115	380.133
23	529	12167	4.7958	2.8439	1.36173	43.4783	72.257	415.476
24	576	13824	4.8990	2.8845	1.38021	41.6667	75.398	452.389
25	625	15625	5.0000	2.9240	1.39794	40.0000	78.540	490.874
26	676	17576	5.0990	2.9625	1.41497	38.4615	81.681	530.929
27	729	19683	5.1962	3.0000	1.43136	37.0370	84,823	572.555
28	784	21952	5.2915	3.0366	1.44716	35.7143	87.965	615.752
29	841	24389	5.3852	3.0723	1.46240	34.4828	91.106	660.520
30	900	27000	5.4772	3.1072	1.47712	33.3333	94.248	706.858
31	961	29791	5.5678	3.1414	1.49136	32.2581	97.389	754.768
32	1024	32768	5.6569	3.1748	1.50515	31.2500	100.531	804.248
33	1089	35937	5.7446	3.2075	1.51851	30.3030	103.673	855.299
34	1156	39304	5.8310	3.2396	1.53148	29.4118	106.814	907.920
35	1225	42875	5.9161	3.2711	1.54407	28.5714	109.956	962.113
36	1296	46656	6.0000	3.3019	1.55630	27.7778	113.097	1017.88
37	1369	50653	6.0828	3.3322	1.56820	27.0270	116.239	1075.21
38	1444	54872	6.1644	3.3620	1.57978	26.3158	119.381	1134.11
39	1521	59319	6.2450	3.3912	1.59106	25.6410	122.522	1194.59
40	1600	64000	6.3246	3.4200	1.60206	25.0000	125.66	1256.64
41	1681	68921	6.4031	3.4482	1.61278	24.3902	128.81	1320.25
42	1764	74088	6.4807	3.4760	1.62325	23.8095	131.95	1385.44
43	1849	79507	6.5574	3.5034	1.63347	23.2558	135.09	1452.20

Table 7. Functions of Numbers (Cont'd)

No.	Square	Cube	Square Root	Cubic Root	Logarithm	1000 x Reciprocal	No. = Diameter	
							Circum.	Area
44	1936	85184	6.6332	3.5303	1.64345	22.7273	138.23	1520.53
45	2025	91125	6.7082	3.5569	1.65321	22.2222	141.37	1590.43
46	2116	97336	6.7823	3.5830	1.66276	21.7391	144.51	1661.90
47	2209	103823	6.8557	3.6088	1.67210	21.2766	147.65	1734.94
48	2304	110592	6.9282	3.6342	1.68124	20.8333	150.80	1809.56
49	2401	117649	7.0000	3.6593	1.69020	20.4082	153.94	1885.74
50	2500	125000	7.0711	3.6840	1.69897	20.0000	157.08	1963.50
51	2601	132651	7.1414	3.7084	1.70757	19.6078	160.22	2042.82
52	2704	140608	7.2111	3.7325	1.71600	19.2308	163.36	2123.72
53	2809	148877	7.2801	3.7563	1.72428	18.8679	166.50	2206.18
54	2916	157464	7.3485	3.7798	1.73239	18.5185	169.65	2290.22
55	3025	166375	7.4162	3.8030	1.74036	18.1818	172.79	2375.83
56	3136	175616	7.4833	3.8259	1.74819	17.8571	175.93	2463.01
57	3249	185193	7.5498	3.8485	1.75587	17.5439	179.07	2551.76
58	3364	195112	7.6158	3.8709	1.76343	17.2414	182.21	2642.08
59	3481	205379	7.6811	3.8930	1.77085	16.9492	185.35	2733.97
60	3600	216000	7.7460	3.9149	1.77815	16.6667	188.50	2827.43
61	3721	226981	7.8102	3.9365	1.78533	16.3934	191.64	2922.47
62	3844	238328	7.8740	3.9579	1.79239	16.1290	194.78	3019.07
63	3969	250047	7.9373	3.9791	1.79934	15.8730	197.92	3117.25
64	4096	262144	8.0000	4.0000	1.80618	15.6250	201.06	3216.99
65	4225	274625	8.0623	4.0207	1.81291	15.3846	204.20	3318.31
66	4356	287496	8.1240	4.0412	1.81954	15.1515	207.35	3421.19
67	4489	300763	8.1854	4.0615	1.82607	14.9254	210.49	3525.65
68	4624	314432	8.2462	4.0817	1.83251	14.7059	213.63	3631.68
69	4761	328509	8.3066	4.1016	1.83885	14.4928	216.77	3739.28
70	4900	343000	8.3666	4.1213	1.84510	14.2857	219.91	3848.45
71	5041	357911	8.4261	4.1408	1.85126	14.0845	223.05	3959.19
72	5184	373248	8.4853	4.1602	1.85733	13.8889	226.19	4071.50
73	5329	389017	8.5440	4.1793	1.86332	13.6986	229.34	4185.39
74	5476	405224	8.6023	4.1983	1.86923	13.5135	232.48	4300.84
75	5625	421875	8.6603	4.2172	1.87506	13.3333	235.62	4417.86
76	5776	438976	8.7178	4.2358	1.88081	13.1579	238.76	4536.46
77	5929	456533	8.7750	4.2543	1.88649	12.9870	241.90	4656.63
78	6084	474552	8.8318	4.2727	1.89209	12.8205	245.04	4778.36
79	6241	493039	8.8882	4.2908	1.89763	12.6582	248.19	4901.67
80	6400	512000	8.9443	4.3089	1.90309	12.5000	251.33	5026.55
81	6561	531441	9.0000	4.3267	1.90849	12.3457	254.47	5153.00
82	6724	551368	9.0554	4.3445	1.91381	12.1951	257.61	5281.02
83	6889	571787	9.1104	4.3621	1.91908	12.0482	260.75	5410.61
84	7056	592704	9.1652	4.3795	1.92428	11.9048	263.89	5541.77
85	7225	614125	9.2195	4.3968	1.92942	11.7647	267.04	5674.50
86	7396	636056	9.2736	4.4140	1.93450	11.6279	270.18	5808.80

Table 7. Functions of Numbers (Cont'd)

No.	Square	Cube	Square Root	Cubic Root	Logarithm	1000 x Reciprocal	No. = Diameter	
							Circum.	Area
87	7569	658503	9.3274	4.4310	1.93952	11.4943	273.32	5944.68
88	7744	681472	9.3808	4.4480	1.94448	11.3636	276.46	6082.12
89	7921	704969	9.4340	4.4647	1.94939	11.2360	279.60	6221.14
90	8100	729000	9.4868	4.4814	1.95424	11.1111	282.74	6361.73
91	8281	753571	9.5394	4.4979	1.95904	10.9890	285.88	6503.88
92	8464	778688	9.5917	4.5144	1.96379	10.8696	289.03	6647.61
93	8649	804357	9.6437	4.5307	1.96848	10.7527	292.17	6792.91
94	8836	830584	9.6954	4.5468	1.97313	10.6383	295.31	6939.78
95	9025	857375	9.7468	4.5629	1.97772	10.5263	298.45	7088.22
96	9216	884736	9.7980	4.5789	1.98227	10.4167	301.59	7238.23
97	9409	912673	9.8489	4.5947	1.98677	10.3093	304.73	7389.81
98	9604	941192	9.8995	4.6104	1.99123	10.2041	307.88	7542.96
99	9801	970299	9.9499	4.6261	1.99564	10.1010	311.02	7697.69

CHAPTER 23

Safety Suggestions

Many of the following safety suggestions are offered by the National Safety Council. They provide some excellent rules to be observed by the amateur workshop operator.

Workshop—Keep the workshop floor clean and free of sawdust and oil. Such refuse creates a fire hazard and makes footing unsure. Never throw inflammable waste into the furnace as it may ignite with considerable force.

When they are not in use, put hand tools away and out of reach of children. Be sure that all power tools are disconnected. It may be advisable to remove the fuse which controls the power-tool circuit or to install a switch lock on each piece of power equipment. It is recommended that all power tools be grounded as an additional safety factor, since an electric shock may cause injury to the operator, particularly when standing on a damp floor. Check electrical cords periodically to see that they are in good condition. Always stop a machine for oiling or adjustments, and never leave machinery when it is running.

Hand Tools—As a general precaution, use the right tool for the job and keep cutting edges sharp to avoid sticking or slipping. Keep the hammer face free from grease and oil. Hold a nail between thumb and forefinger near nail head, keep your eye on the head, and strike the nail squarely. Use a screwdriver that fits the screw and seat the blade squarely against the bottom of the screw slot. Never hold the work in the hand. When sawing, start the work slowly and carefully until the cut is deep enough to prevent a sidewise slip.

Safety Suggestions

When using a cold chisel on metal, wear goggles to guard against flying fragments. Keep wood chisels sharp and their handles sound and tight. When planing, avoid a dull or nicked blade which may jam or slip and keep hands clear of the material.

Power Tools—Since power tools represent a considerable investment, they should be properly operated and maintained for trouble-free service. One of the power tools most prized by the home craftsman is the circular saw, the operation of which requires concentration and care. Be sure the saw is equipped with a guard and use it. When ripping short and narrow material, always use a push stick. In holding work with the hands, keep a firm grip to prevent both material and hands from slipping.

Do not stand directly in front of the saw blade where material may kick back, and never reach around or over the saw blade when it is in motion. Again, concentrate your attention on the job at all times and do not permit distractions. When operating a grinder, wear goggles and be sure the wheel has a protective hood. Use only the face of the wheel unless it is designed for grinding on the side, as side pressure may cause it to break. Avoid blows or excessive pressure and hold tools firmly. Do not wear gloves or hold the tool with a rag which may get caught.

When operating a woodturning lathe, be sure the stock to be turned has no split ends or loose knots. Set the tool rest slightly below the center line of the stock to prevent catching or throwing of the tool. Check for work clearance by first revolving the stock by hand. Operate at the slowest lathe speed until the stock is fully cylindrical. Turn off power to test stock, to make adjustments, or to use calipers. Keep lathe tools sharp and see that they have good strong handles.

When using a power drill, the material should be clamped securely to the workbench or held in a vise. If the twist drill jams in the material, stop the motor and release the drill by hand. Do not wear gloves when operating a drill press. Apply SAFETY FIRST in the workshop at all times, and the chances of mishap will be reduced to a minimum.

INDEX

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